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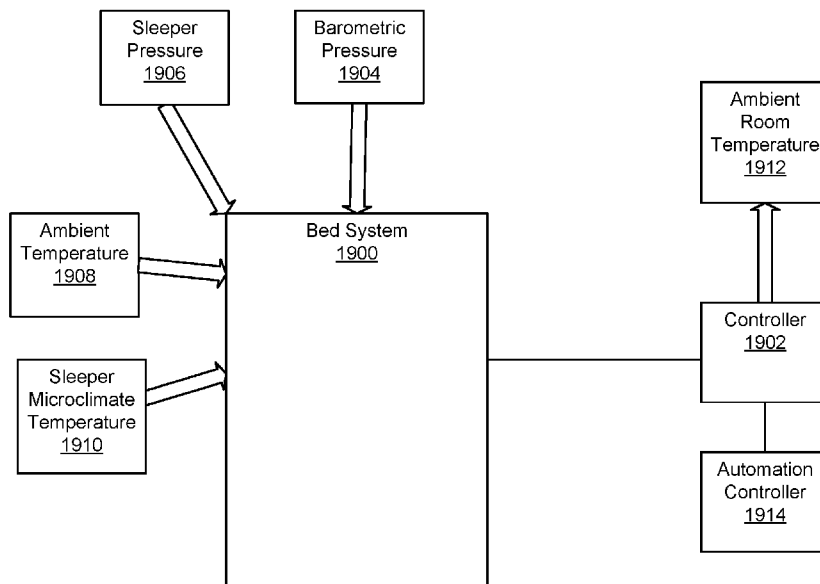


FIG. 19

(57) Abstract: Bladder pressure readings of bladder pressure inside an air bladder of a mattress are received for a particular time. Barometric pressure readings of barometric pressure in an ambient environment outside the mattress are received for the particular time. The bladder pressure and the barometric pressure readings are used as input to an ambient temperature classifier. Output from the ambient temperature classifier is received as an ambient temperature value for the particular time.



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**AIR MATTRESS WITH FEATURES FOR DETERMINING AMBIENT TEMPURATURE**

[0001] The present document relates to automation of a consumer device such as an airbed.

**CROSS-REFERENCE TO RELATED APPLICATIONS**

[0002] This application claims the benefit of U.S. Provisional Application Serial No. 63/279,427,  
5 filed November 15, 2021. The disclosure of the prior application is considered part of (and is incorporated  
by reference in) the disclosure of this application.

**BACKGROUND**

[0003] In general, a bed is a piece of furniture used as a location to sleep or relax. Many modern  
10 beds include a soft mattress on a bed frame. The mattress may include springs, foam material, and/or an air  
chamber to support the weight of one or more occupants.

**SUMMARY**

[0004] The present document generally relates to modifying an ambient environment based on  
determining ambient temperature values. A bed system can include multiple sensors that can be configured  
15 to detect different types of pressure signals at the bed system. The multiple sensors can include a  
barometric sensor, a microclimate temperature sensor, and an air bladder pressure sensor. A controller for  
the bed system in communication with the multiple sensors can receive the pressure signals and, using an  
ambient temperature classifier, determine an ambient temperature value based on the received pressure  
signals.

20 [0005] The ambient temperature value can indicate a temperature of an environment, such as a  
room, where the bed system is located. Based on the determined ambient temperature value, the controller  
can determine and/or initiate one or more home automation events. The home automation events can  
include adjusting a temperature in the room, such as turning a heating, ventilation, and air conditioning  
(HVAC) unit on or off in the home. The home automation events can also include adjusting settings of the  
25 bed system, such as turning heating or cooling elements on or off, adjusting pressure (e.g., firmness)

settings of the bed system, and/or adjusting positioning of portions of the bed system (e.g., raising a head portion of the bed system, lowering a foot portion, etc.). One or more other home automation events are also possible.

[0006] A system of one or more computers can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One or more computer programs can be configured to perform particular operations or actions by virtue of including instructions that, when executed by data processing apparatus, cause the apparatus to perform the actions. One general aspect includes a system for measuring ambient temperature. The system includes a mattress for supporting a sleeper. The mattress includes at least one air bladder. The system also includes a bladder pressure sensor fluidically coupled to the air bladder, the bladder pressure sensor configured to: sense bladder pressure inside the air bladder for a particular time and transmit bladder pressure readings for the particular time. The system also includes a barometric sensor in an ambient environment outside the mattress, the barometric sensor configured to: sense barometric pressure in the ambient environment for the particular time and transmit barometric pressure readings for the particular time. The system also includes a computing device including at least one processor and memory, the computing device configured to: receive the bladder pressure readings, receive the barometric pressure readings, provide, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings, and receive, as output from the ambient temperature classifier, an ambient temperature value for the particular time. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0007] Implementations may include one or more of the following features. The ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure. The ambient temperature classifier is configured to: determine a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and determine the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature. The model is based on an ideal gas law. The contents of the air bladder include both a gas and an open cell foam, and

where the model is further based on thermal expansion properties of the open cell foam. The ambient temperature classifier is configured to find the ambient temperature by looking up the ambient temperature in a lookup table indexed by bladder pressure and barometric pressure. The ambient temperature classifier was trained with machine learning processes using training data with i) bladder pressure reading:barometric pressure reading pairs and ii) training ambient temperature values. The system further may include a temperature sensor configured to: sense microclimate temperature in a microclimate around the sleeper; transmit the microclimate temperature readings for the particular time. The computing device is further configured to: receive the microclimate temperature readings; and provide, as further input to the ambient temperature classifier, the microclimate temperature readings. The ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure and of the microclimate temperature on the bladder pressure. The computing device is further configured to identify discontinuities, greater than a threshold value, in a record of ambient pressure values over time as bed entry/exit events. The computing device is further configured to initiate a home automation event based on the received ambient temperature value for the particular time. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

**[0008]** One general aspect includes a computer-readable medium tangibly storing instructions that, when executed by one or more processors, cause the one or more processors to perform operations. The operations include to receive bladder pressure readings of bladder pressure inside an air bladder of a mattress for a particular time; receive barometric pressure readings of barometric pressure in an ambient environment outside the mattress for the particular time; provide, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings; and receive, as output from the ambient temperature classifier, an ambient temperature value for the particular time. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

**[0009]** Implementations may include one or more of the following features. The ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure. The ambient temperature classifier is

configured to: determine a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and determine the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature. The model is based on an ideal gas law. The contents of the air bladder include both a gas and an open cell foam, and the model is further based on thermal expansion properties of the open cell foam. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

**[0010]** One general aspect includes a method for measuring ambient temperature. The method includes receiving bladder pressure readings of bladder pressure inside an air bladder of a mattress for a particular time; receiving barometric pressure readings of barometric pressure in an ambient environment outside the mattress for the particular time; providing, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings; and receiving, as output from the ambient temperature classifier, an ambient temperature value for the particular time. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

**[0011]** Implementations may include one or more of the following features. The method may include determining, by the ambient temperature classifier, temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure. The method may include determining, by the ambient temperature classifier, a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and determining, by the ambient temperature classifier, the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature. The model is based on an ideal gas law. Implementations of the described techniques may include hardware, a method or process, or computer software on a computer-accessible medium.

**[0012]** Implementations can include any, all, or none of the following features and advantages. For example, the disclosed techniques provide for automatic adjustment of ambient settings in an environment surrounding the bed system. A user can be sleeping in the bed system when a temperature in a room where the user is sleeping is rising. The multiple sensors configured to or in communication with the

bed system can detect changes in pressure that cause the room temperature to rise. The controller can receive the detected sensor values and determine the temperature in the room. If the room temperature exceeds some threshold value, then the controller can determine that the room temperature should be adjusting by turning on an HVAC unit in the home. Thus, the temperature of the room can be adjusted to a more desirable temperature while the user is asleep, and without waking up the user. The user can therefore continue to experience comfortable and uninterrupted sleep.

[0013] As yet another example, the disclosed techniques allow for the bed system to act like a sensor. The bed system can efficiently track objects, such as users as they sleep, exit the bed system, and/or enter the bed system. The bed system can serve multiple purposes other than just a surface for users to sleep on by providing for improved home automation techniques to be determined and performed.

[0014] As another example, one or more of the multiple sensors described herein can cost less than other sensors. A barometric sensor can measure both barometric pressure and air temperature surrounding the bed system. The sensor can measure two different types of signals at a lower cost, thereby making implementation of the barometric sensor more affordable and attractive.

[0015] Other features, aspects and potential advantages will be apparent from the accompanying description and figures.

#### DESCRIPTION OF DRAWINGS

[0016] FIG. 1 shows an example air bed system.

[0017] FIG. 2 is a block diagram of an example of various components of an air bed system.

[0018] FIG. 3 shows an example environment including a bed in communication with devices located in and around a home.

[0019] FIGs. 4A and 4B are block diagrams of example data processing systems that can be associated with a bed.

[0020] FIGs. 5 and 6 are block diagrams of examples of motherboards that can be used in a data processing system that can be associated with a bed.

[0021] FIG. 7 is a block diagram of an example of a daughterboard that can be used in a data processing system that can be associated with a bed.

[0022] FIG. 8 is a block diagram of an example of a motherboard with no daughterboard that can be used in a data processing system that can be associated with a bed.

[0023] FIG. 9 is a block diagram of an example of a sensory array that can be used in a data processing system that can be associated with a bed.

5 [0024] FIG. 10 is a block diagram of an example of a control array that can be used in a data processing system that can be associated with a bed

[0025] FIG. 11 is a block diagram of an example of a computing device that can be used in a data processing system that can be associated with a bed.

10 [0026] FIGs. 12-16 are block diagrams of example cloud services that can be used in a data processing system that can be associated with a bed.

[0027] FIG. 17 is a block diagram of an example of using a data processing system that can be associated with a bed to automate peripherals around the bed.

[0028] FIG. 18 is a schematic diagram that shows an example of a computing device and a mobile computing device.

15 [0029] FIG. 19 is a block diagram of an example bed system for determining ambient temperature in an environment surrounding the bed system.

[0030] FIG. 20 is a block diagram of components of the example bed system that can be used to determine ambient temperature in the environment surrounding the bed system.

20 [0031] FIG. 21 is a swimlane diagram of an example process for initiating a home automation event based on determining ambient temperature in an environment surrounding the example bed system of FIG. 19.

[0032] Like reference symbols in the various drawings indicate like elements.

#### **DETAILED DESCRIPTION**

25 [0033] This document generally relates to modifying an ambient environment based on determining ambient temperature values surrounding a bed system. The bed system can include (and/or be in communication with) multiple sensors that detect different types of pressure signals at the bed system. The multiple sensors can include a barometric sensor for measuring barometric pressure applied to the bed system, a microclimate temperature sensor for measuring temperature on a top surface of the bed system

(e.g., user body temperature), and an air bladder pressure sensor for measuring pressure applied to an air bladder of the bed system. A controller for the bed system in communication with the multiple sensors can receive the pressure signals and, using an ambient temperature classifier, determine an ambient temperature value based on the pressure signals.

5 [0034] The ambient temperature value can indicate a temperature of an environment, such as a room, where the bed system is located. Based on the determined ambient temperature value, the controller can determine and/or initiate one or more home automation events. The home automation events can include adjusting a temperature in the room, such as turning an HVAC unit on or off in the home. The home automation events can also include adjusting settings of the bed system, such as turning heating or cooling  
10 elements on or off, adjusting pressure (e.g., firmness) settings of the bed system, and/or adjusting positioning of portions of the bed system (e.g., raising a head portion of the bed system, lowering a foot portion, etc.). One or more other home automation events are also possible.

[0035] **Example Airbed Hardware**

[0036] FIG. 1 shows an example air bed system 100 that includes a bed 112. The bed 112  
15 includes at least one air chamber 114 surrounded by a resilient border 116 and encapsulated by bed ticking 118. The resilient border 116 can comprise any suitable material, such as foam.

[0037] As illustrated in FIG. 1, the bed 112 can be a two chamber design having first and second fluid chambers, such as a first air chamber 114A and a second air chamber 114B. In alternative  
20 embodiments, the bed 112 can include chambers for use with fluids other than air that are suitable for the application. In some embodiments, such as single beds or kids' beds, the bed 112 can include a single air chamber 114A or 114B or multiple air chambers 114A and 114B. First and second air chambers 114A and 114B can be in fluid communication with a pump 120. The pump 120 can be in electrical communication with a remote control 122 via control box 124. The control box 124 can include a wired or wireless communications interface for communicating with one or more devices, including the remote control 122.  
25 The control box 124 can be configured to operate the pump 120 to cause increases and decreases in the fluid pressure of the first and second air chambers 114A and 114B based upon commands input by a user using the remote control 122. In some implementations, the control box 124 is integrated into a housing of the pump 120.

[0038] The remote control 122 can include a display 126, an output selecting mechanism 128, a pressure increase button 129, and a pressure decrease button 130. The output selecting mechanism 128 can allow the user to switch air flow generated by the pump 120 between the first and second air chambers 114A and 114B, thus enabling control of multiple air chambers with a single remote control 122 and a single pump 120. For example, the output selecting mechanism 128 can be by a physical control (e.g., switch or button) or an input control displayed on display 126. Alternatively, separate remote control units can be provided for each air chamber and can each include the ability to control multiple air chambers. Pressure increase and decrease buttons 129 and 130 can allow a user to increase or decrease the pressure, respectively, in the air chamber selected with the output selecting mechanism 128. Adjusting the pressure within the selected air chamber can cause a corresponding adjustment to the firmness of the respective air chamber. In some embodiments, the remote control 122 can be omitted or modified as appropriate for an application. For example, in some embodiments the bed 112 can be controlled by a computer, tablet, smart phone, or other device in wired or wireless communication with the bed 112.

[0039] FIG. 2 is a block diagram of an example of various components of an air bed system. For example, these components can be used in the example air bed system 100. As shown in FIG. 2, the control box 124 can include a power supply 134, a processor 136, a memory 137, a switching mechanism 138, and an analog to digital (A/D) converter 140. The switching mechanism 138 can be, for example, a relay or a solid state switch. In some implementations, the switching mechanism 138 can be located in the pump 120 rather than the control box 124.

[0040] The pump 120 and the remote control 122 are in two-way communication with the control box 124. The pump 120 includes a motor 142, a pump manifold 143, a relief valve 144, a first control valve 145A, a second control valve 145B, and a pressure transducer 146. The pump 120 is fluidly connected with the first air chamber 114A and the second air chamber 114B via a first tube 148A and a second tube 148B, respectively. The first and second control valves 145A and 145B can be controlled by switching mechanism 138, and are operable to regulate the flow of fluid between the pump 120 and first and second air chambers 114A and 114B, respectively.

[0041] In some implementations, the pump 120 and the control box 124 can be provided and packaged as a single unit. In some alternative implementations, the pump 120 and the control box 124 can

be provided as physically separate units. In some implementations, the control box 124, the pump 120, or both are integrated within or otherwise contained within a bed frame or bed support structure that supports the bed 112. In some implementations, the control box 124, the pump 120, or both are located outside of a bed frame or bed support structure (as shown in the example in FIG 1).

5 [0042] The example air bed system 100 depicted in FIG. 2 includes the two air chambers 114A and 114B and the single pump 120. However, other implementations can include an air bed system having two or more air chambers and one or more pumps incorporated into the air bed system to control the air chambers. For example, a separate pump can be associated with each air chamber of the air bed system or a pump can be associated with multiple chambers of the air bed system. Separate pumps can allow each air  
10 chamber to be inflated or deflated independently and simultaneously. Furthermore, additional pressure transducers can also be incorporated into the air bed system such that, for example, a separate pressure transducer can be associated with each air chamber.

[0043] In use, the processor 136 can, for example, send a decrease pressure command to one of air chambers 114A or 114B, and the switching mechanism 138 can be used to convert the low voltage  
15 command signals sent by the processor 136 to higher operating voltages sufficient to operate the relief valve 144 of the pump 120 and open the control valve 145A or 145B. Opening the relief valve 144 can allow air to escape from the air chamber 114A or 114B through the respective air tube 148A or 148B. During deflation, the pressure transducer 146 can send pressure readings to the processor 136 via the A/D converter 140. The A/D converter 140 can receive analog information from pressure transducer 146 and  
20 can convert the analog information to digital information useable by the processor 136. The processor 136 can send the digital signal to the remote control 122 to update the display 126 in order to convey the pressure information to the user.

[0044] As another example, the processor 136 can send an increase pressure command. The pump motor 142 can be energized in response to the increase pressure command and send air to the  
25 designated one of the air chambers 114A or 114B through the air tube 148A or 148B via electronically operating the corresponding valve 145A or 145B. While air is being delivered to the designated air chamber 114A or 114B in order to increase the firmness of the chamber, the pressure transducer 146 can sense pressure within the pump manifold 143. Again, the pressure transducer 146 can send pressure readings to

the processor 136 via the A/D converter 140. The processor 136 can use the information received from the A/D converter 140 to determine the difference between the actual pressure in air chamber 114A or 114B and the desired pressure. The processor 136 can send the digital signal to the remote control 122 to update display 126 in order to convey the pressure information to the user.

5 [0045] Generally speaking, during an inflation or deflation process, the pressure sensed within the pump manifold 143 can provide an approximation of the pressure within the respective air chamber that is in fluid communication with the pump manifold 143. An example method of obtaining a pump manifold pressure reading that is substantially equivalent to the actual pressure within an air chamber includes turning off pump 120, allowing the pressure within the air chamber 114A or 114B and the pump manifold  
10 143 to equalize, and then sensing the pressure within the pump manifold 143 with the pressure transducer 146. Thus, providing a sufficient amount of time to allow the pressures within the pump manifold 143 and chamber 114A or 114B to equalize can result in pressure readings that are accurate approximations of the actual pressure within air chamber 114A or 114B. In some implementations, the pressure of the air chambers 114A and/or 114B can be continuously monitored using multiple pressure sensors (not shown).

15 [0046] In some implementations, information collected by the pressure transducer 146 can be analyzed to determine various states of a person lying on the bed 112. For example, the processor 136 can use information collected by the pressure transducer 146 to determine a heart rate or a respiration rate for a person lying in the bed 112. For example, a user can be lying on a side of the bed 112 that includes the chamber 114A. The pressure transducer 146 can monitor fluctuations in pressure of the chamber 114A and  
20 this information can be used to determine the user's heart rate and/or respiration rate. As another example, additional processing can be performed using the collected data to determine a sleep state of the person (e.g., awake, light sleep, deep sleep). For example, the processor 136 can determine when a person falls asleep and, while asleep, the various sleep states of the person.

[0047] Additional information associated with a user of the air bed system 100 that can be  
25 determined using information collected by the pressure transducer 146 includes motion of the user, presence of the user on a surface of the bed 112, weight of the user, heart arrhythmia of the user, and apnea. Taking user presence detection for example, the pressure transducer 146 can be used to detect the user's presence on the bed 112, e.g., via a gross pressure change determination and/or via one or more of a

respiration rate signal, heart rate signal, and/or other biometric signals. For example, a simple pressure detection process can identify an increase in pressure as an indication that the user is present on the bed 112. As another example, the processor 136 can determine that the user is present on the bed 112 if the detected pressure increases above a specified threshold (so as to indicate that a person or other object above a certain weight is positioned on the bed 112). As yet another example, the processor 136 can identify an increase in pressure in combination with detected slight, rhythmic fluctuations in pressure as corresponding to the user being present on the bed 112. The presence of rhythmic fluctuations can be identified as being caused by respiration or heart rhythm (or both) of the user. The detection of respiration or a heartbeat can distinguish between the user being present on the bed and another object (e.g., a suit case) being placed upon the bed.

[0048] In some implementations, fluctuations in pressure can be measured at the pump 120. For example, one or more pressure sensors can be located within one or more internal cavities of the pump 120 to detect fluctuations in pressure within the pump 120. The fluctuations in pressure detected at the pump 120 can indicate fluctuations in pressure in one or both of the chambers 114A and 114B. One or more sensors located at the pump 120 can be in fluid communication with the one or both of the chambers 114A and 114B, and the sensors can be operative to determine pressure within the chambers 114A and 114B. The control box 124 can be configured to determine at least one vital sign (e.g., heart rate, respiratory rate) based on the pressure within the chamber 114A or the chamber 114B.

[0049] In some implementations, the control box 124 can analyze a pressure signal detected by one or more pressure sensors to determine a heart rate, respiration rate, and/or other vital signs of a user lying or sitting on the chamber 114A or the chamber 114B. More specifically, when a user lies on the bed 112 positioned over the chamber 114A, each of the user's heart beats, breaths, and other movements can create a force on the bed 112 that is transmitted to the chamber 114A. As a result of the force input to the chamber 114A from the user's movement, a wave can propagate through the chamber 114A and into the pump 120. A pressure sensor located at the pump 120 can detect the wave, and thus the pressure signal output by the sensor can indicate a heart rate, respiratory rate, or other information regarding the user.

[0050] With regard to sleep state, air bed system 100 can determine a user's sleep state by using various biometric signals such as heart rate, respiration, temperature, and/or movement of the user. While

the user is sleeping, the processor 136 can receive one or more of the user's biometric signals (e.g., heart rate, respiration, and motion) and determine the user's present sleep state based on the received biometric signals. In some implementations, signals indicating fluctuations in pressure in one or both of the chambers 114A and 114B can be amplified and/or filtered to allow for more precise detection of heart rate and respiratory rate.

5 [0051] The control box 124 can perform a pattern recognition algorithm or other calculation based on the amplified and filtered pressure signal to determine the user's heart rate and respiratory rate. For example, the algorithm or calculation can be based on assumptions that a heart rate portion of the signal has a frequency in the range of 0.5-4.0 Hz and that a respiration rate portion of the signal has a frequency in the range of less than 1 Hz. The control box 124 can also be configured to determine other characteristics of a user based on the received pressure signal, such as blood pressure, tossing and turning movements, rolling movements, limb movements, weight, the presence or lack of presence of a user, and/or the identity of the user. Techniques for monitoring a user's sleep using heart rate information, respiration rate information, and other user information are disclosed in U.S. Patent Application Publication No. 10 20100170043 to Steven J. Young et al., titled "APPARATUS FOR MONITORING VITAL SIGNS," the entire contents of which is incorporated herein by reference.

[0052] For example, the pressure transducer 146 can be used to monitor the air pressure in the chambers 114A and 114B of the bed 112. If the user on the bed 112 is not moving, the air pressure changes in the air chamber 114A or 114B can be relatively minimal, and can be attributable to respiration and/or 20 heartbeat. When the user on the bed 112 is moving, however, the air pressure in the mattress can fluctuate by a much larger amount. Thus, the pressure signals generated by the pressure transducer 146 and received by the processor 136 can be filtered and indicated as corresponding to motion, heartbeat, or respiration.

[0053] In some implementations, rather than performing the data analysis in the control box 124 with the processor 136, a digital signal processor (DSP) can be provided to analyze the data collected by the pressure transducer 146. Alternatively, the data collected by the pressure transducer 146 could be sent 25 to a cloud-based computing system for remote analysis.

[0054] In some implementations, the example air bed system 100 further includes a temperature controller configured to increase, decrease, or maintain the temperature of a bed, for example for the

comfort of the user. For example, a pad can be placed on top of or be part of the bed 112, or can be placed on top of or be part of one or both of the chambers 114A and 114B. Air can be pushed through the pad and vented to cool off a user of the bed. Conversely, the pad can include a heating element that can be used to keep the user warm. In some implementations, the temperature controller can receive temperature readings from the pad. In some implementations, separate pads are used for the different sides of the bed 112 (e.g., corresponding to the locations of the chambers 114A and 114B) to provide for differing temperature control for the different sides of the bed.

[0055] In some implementations, the user of the air bed system 100 can use an input device, such as the remote control 122, to input a desired temperature for the surface of the bed 112 (or for a portion of the surface of the bed 112). The desired temperature can be encapsulated in a command data structure that includes the desired temperature as well as identifies the temperature controller as the desired component to be controlled. The command data structure can then be transmitted via Bluetooth or another suitable communication protocol to the processor 136. In various examples, the command data structure is encrypted before being transmitted. The temperature controller can then configure its elements to increase or decrease the temperature of the pad depending on the temperature input into remote control 122 by the user.

[0056] In some implementations, data can be transmitted from a component back to the processor 136 or to one or more display devices, such as the display 126. For example, the current temperature as determined by a sensor element of temperature controller, the pressure of the bed, the current position of the foundation or other information can be transmitted to control box 124. The control box 124 can then transmit the received information to remote control 122 where it can be displayed to the user (e.g., on the display 126).

[0057] In some implementations, the example air bed system 100 further includes an adjustable foundation and an articulation controller configured to adjust the position of a bed (e.g., the bed 112) by adjusting the adjustable foundation that supports the bed. For example, the articulation controller can adjust the bed 112 from a flat position to a position in which a head portion of a mattress of the bed is inclined upward (e.g., to facilitate a user sitting up in bed and/or watching television). In some implementations, the bed 112 includes multiple separately articulable sections. For example, portions of

the bed corresponding to the locations of the chambers 114A and 114B can be articulated independently from each other, to allow one person positioned on the bed 112 surface to rest in a first position (e.g., a flat position) while a second person rests in a second position (e.g., an reclining position with the head raised at an angle from the waist). In some implementations, separate positions can be set for two different beds (e.g., two twin beds placed next to each other). The foundation of the bed 112 can include more than one zone that can be independently adjusted. The articulation controller can also be configured to provide different levels of massage to one or more users on the bed 112.

**[0058] Example of a Bed in a Bedroom Environment**

**[0059]** FIG. 3 shows an example environment 300 including a bed 302 in communication with devices located in and around a home. In the example shown, the bed 302 includes pump 304 for controlling air pressure within two air chambers 306a and 306b (as described above with respect to the air chambers 114A-114B). The pump 304 additionally includes circuitry for controlling inflation and deflation functionality performed by the pump 304. The circuitry is further programmed to detect fluctuations in air pressure of the air chambers 306a-b and used the detected fluctuations in air pressure to identify bed presence of a user 308, sleep state of the user 308, movement of the user 308, and biometric signals of the user 308 such as heart rate and respiration rate. In the example shown, the pump 304 is located within a support structure of the bed 302 and the control circuitry 334 for controlling the pump 304 is integrated with the pump 304. In some implementations, the control circuitry 334 is physically separate from the pump 304 and is in wireless or wired communication with the pump 304. In some implementations, the pump 304 and/or control circuitry 334 are located outside of the bed 302. In some implementations, various control functions can be performed by systems located in different physical locations. For example, circuitry for controlling actions of the pump 304 can be located within a pump casing of the pump 304 while control circuitry 334 for performing other functions associated with the bed 302 can be located in another portion of the bed 302, or external to the bed 302. As another example, control circuitry 334 located within the pump 304 can communicate with control circuitry 334 at a remote location through a LAN or WAN (e.g., the internet). As yet another example, the control circuitry 334 can be included in the control box 124 of FIGs. 1 and 2.

[0060] In some implementations, one or more devices other than, or in addition to, the pump 304 and control circuitry 334 can be utilized to identify user bed presence, sleep state, movement, and biometric signals. For example, the bed 302 can include a second pump in addition to the pump 304, with each of the two pumps connected to a respective one of the air chambers 306a-b. For example, the pump 304 can be in fluid communication with the air chamber 306b to control inflation and deflation of the air chamber 306b as well as detect user signals for a user located over the air chamber 306b such as bed presence, sleep state, movement, and biometric signals while the second pump is in fluid communication with the air chamber 306a to control inflation and deflation of the air chamber 306a as well as detect user signals for a user located over the air chamber 306a.

[0061] As another example, the bed 302 can include one or more pressure sensitive pads or surface portions that are operable to detect movement, including user presence, user motion, respiration, and heart rate. For example, a first pressure sensitive pad can be incorporated into a surface of the bed 302 over a left portion of the bed 302, where a first user would normally be located during sleep, and a second pressure sensitive pad can be incorporated into the surface of the bed 302 over a right portion of the bed 302, where a second user would normally be located during sleep. The movement detected by the one or more pressure sensitive pads or surface portions can be used by control circuitry 334 to identify user sleep state, bed presence, or biometric signals.

[0062] In some implementations, information detected by the bed (e.g., motion information) is processed by control circuitry 334 (e.g., control circuitry 334 integrated with the pump 304) and provided to one or more user devices such as a user device 310 for presentation to the user 308 or to other users. In the example depicted in FIG. 3, the user device 310 is a tablet device; however, in some implementations, the user device 310 can be a personal computer, a smart phone, a smart television (e.g., a television 312), or other user device capable of wired or wireless communication with the control circuitry 334. The user device 310 can be in communication with control circuitry 334 of the bed 302 through a network or through direct point-to-point communication. For example, the control circuitry 334 can be connected to a LAN (e.g., through a Wi-Fi router) and communicate with the user device 310 through the LAN. As another example, the control circuitry 334 and the user device 310 can both connect to the Internet and communicate through the Internet. For example, the control circuitry 334 can connect to the Internet

through a WiFi router and the user device 310 can connect to the Internet through communication with a cellular communication system. As another example, the control circuitry 334 can communicate directly with the user device 310 through a wireless communication protocol such as Bluetooth. As yet another example, the control circuitry 334 can communicate with the user device 310 through a wireless communication protocol such as ZigBee, Z-Wave, infrared, or another wireless communication protocol suitable for the application. As another example, the control circuitry 334 can communicate with the user device 310 through a wired connection such as, for example, a USB connector, serial/RS232, or another wired connection suitable for the application.

**[0063]** The user device 310 can display a variety of information and statistics related to sleep, or user 308's interaction with the bed 302. For example, a user interface displayed by the user device 310 can present information including amount of sleep for the user 308 over a period of time (e.g., a single evening, a week, a month, etc.) amount of deep sleep, ratio of deep sleep to restless sleep, time lapse between the user 308 getting into bed and the user 308 falling asleep, total amount of time spent in the bed 302 for a given period of time, heart rate for the user 308 over a period of time, respiration rate for the user 308 over a period of time, or other information related to user interaction with the bed 302 by the user 308 or one or more other users of the bed 302. In some implementations, information for multiple users can be presented on the user device 310, for example information for a first user positioned over the air chamber 306a can be presented along with information for a second user positioned over the air chamber 306b. In some implementations, the information presented on the user device 310 can vary according to the age of the user 308. For example, the information presented on the user device 310 can evolve with the age of the user 308 such that different information is presented on the user device 310 as the user 308 ages as a child or an adult.

**[0064]** The user device 310 can also be used as an interface for the control circuitry 334 of the bed 302 to allow the user 308 to enter information. The information entered by the user 308 can be used by the control circuitry 334 to provide better information to the user or to various control signals for controlling functions of the bed 302 or other devices. For example, the user can enter information such as weight, height, and age and the control circuitry 334 can use this information to provide the user 308 with a comparison of the user's tracked sleep information to sleep information of other people having similar

weights, heights, and/or ages as the user 308. As another example, the user 308 can use the user device 310 as an interface for controlling air pressure of the air chambers 306a and 306b, for controlling various recline or incline positions of the bed 302, for controlling temperature of one or more surface temperature control devices of the bed 302, or for allowing the control circuitry 334 to generate control signals for other devices (as described in greater detail below).

**[0065]** In some implementations, control circuitry 334 of the bed 302 (e.g., control circuitry 334 integrated into the pump 304) can communicate with other first, second, or third party devices or systems in addition to or instead of the user device 310. For example, the control circuitry 334 can communicate with the television 312, a lighting system 314, a thermostat 316, a security system 318, or other house hold devices such as an oven 322, a coffee maker 324, a lamp 326, and a nightlight 328. Other examples of devices and/or systems that the control circuitry 334 can communicate with include a system for controlling window blinds 330, one or more devices for detecting or controlling the states of one or more doors 332 (such as detecting if a door is open, detecting if a door is locked, or automatically locking a door), and a system for controlling a garage door 320 (e.g., control circuitry 334 integrated with a garage door opener for identifying an open or closed state of the garage door 320 and for causing the garage door opener to open or close the garage door 320). Communications between the control circuitry 334 of the bed 302 and other devices can occur through a network (e.g., a LAN or the Internet) or as point-to-point communication (e.g., using Bluetooth, radio communication, or a wired connection). In some implementations, control circuitry 334 of different beds 302 can communicate with different sets of devices. For example, a kid bed may not communicate with and/or control the same devices as an adult bed. In some embodiments, the bed 302 can evolve with the age of the user such that the control circuitry 334 of the bed 302 communicates with different devices as a function of age of the user.

**[0066]** The control circuitry 334 can receive information and inputs from other devices/systems and use the received information and inputs to control actions of the bed 302 or other devices. For example, the control circuitry 334 can receive information from the thermostat 316 indicating a current environmental temperature for a house or room in which the bed 302 is located. The control circuitry 334 can use the received information (along with other information) to determine if a temperature of all or a portion of the surface of the bed 302 should be raised or lowered. The control circuitry 334 can then cause

a heating or cooling mechanism of the bed 302 to raise or lower the temperature of the surface of the bed 302. For example, the user 308 can indicate a desired sleeping temperature of 74 degrees while a second user of the bed 302 indicates a desired sleeping temperature of 72 degrees. The thermostat 316 can indicate to the control circuitry 334 that the current temperature of the bedroom is 72 degrees. The control circuitry 334 can identify that the user 308 has indicated a desired sleeping temperature of 74 degrees, and send control signals to a heating pad located on the user 308's side of the bed to raise the temperature of the portion of the surface of the bed 302 where the user 308 is located to raise the temperature of the user 308's sleeping surface to the desired temperature.

[0067] The control circuitry 334 can also generate control signals controlling other devices and propagate the control signals to the other devices. In some implementations, the control signals are generated based on information collected by the control circuitry 334, including information related to user interaction with the bed 302 by the user 308 and/or one or more other users. In some implementations, information collected from one or more other devices other than the bed 302 are used when generating the control signals. For example, information relating to environmental occurrences (e.g., environmental temperature, environmental noise level, and environmental light level), time of day, time of year, day of the week, or other information can be used when generating control signals for various devices in communication with the control circuitry 334 of the bed 302. For example, information on the time of day can be combined with information relating to movement and bed presence of the user 308 to generate control signals for the lighting system 314. In some implementations, rather than or in addition to providing control signals for one or more other devices, the control circuitry 334 can provide collected information (e.g., information related to user movement, bed presence, sleep state, or biometric signals for the user 308) to one or more other devices to allow the one or more other devices to utilize the collected information when generating control signals. For example, control circuitry 334 of the bed 302 can provide information relating to user interactions with the bed 302 by the user 308 to a central controller (not shown) that can use the provided information to generate control signals for various devices, including the bed 302.

[0068] Still referring to FIG. 3, the control circuitry 334 of the bed 302 can generate control signals for controlling actions of other devices, and transmit the control signals to the other devices in response to information collected by the control circuitry 334, including bed presence of the user 308, sleep

state of the user 308, and other factors. For example, control circuitry 334 integrated with the pump 304 can detect a feature of a mattress of the bed 302, such as an increase in pressure in the air chamber 306b, and use this detected increase in air pressure to determine that the user 308 is present on the bed 302. In some implementations, the control circuitry 334 can identify a heart rate or respiratory rate for the user 308 to identify that the increase in pressure is due to a person sitting, laying, or otherwise resting on the bed 302 rather than an inanimate object (such as a suitcase) having been placed on the bed 302. In some implementations, the information indicating user bed presence is combined with other information to identify a current or future likely state for the user 308. For example, a detected user bed presence at 11:00am can indicate that the user is sitting on the bed (e.g., to tie her shoes, or to read a book) and does not intend to go to sleep, while a detected user bed presence at 10:00pm can indicate that the user 308 is in bed for the evening and is intending to fall asleep soon. As another example, if the control circuitry 334 detects that the user 308 has left the bed 302 at 6:30am (e.g., indicating that the user 308 has woken up for the day), and then later detects user bed presence of the user 308 at 7:30am, the control circuitry 334 can use this information that the newly detected user bed presence is likely temporary (e.g., while the user 308 ties her shoes before heading to work) rather than an indication that the user 308 is intending to stay on the bed 302 for an extended period.

[0069] In some implementations, the control circuitry 334 is able to use collected information (including information related to user interaction with the bed 302 by the user 308, as well as environmental information, time information, and input received from the user) to identify use patterns for the user 308. For example, the control circuitry 334 can use information indicating bed presence and sleep states for the user 308 collected over a period of time to identify a sleep pattern for the user. For example, the control circuitry 334 can identify that the user 308 generally goes to bed between 9:30pm and 10:00pm, generally falls asleep between 10:00pm and 11:00pm, and generally wakes up between 6:30am and 6:45am based on information indicating user presence and biometrics for the user 308 collected over a week. The control circuitry 334 can use identified patterns for a user to better process and identify user interactions with the bed 302 by the user 308.

[0070] For example, given the above example user bed presence, sleep, and wake patterns for the user 308, if the user 308 is detected as being on the bed at 3:00pm, the control circuitry 334 can

determine that the user's presence on the bed is only temporary, and use this determination to generate different control signals than would be generated if the control circuitry 334 determined that the user 308 was in bed for the evening. As another example, if the control circuitry 334 detects that the user 308 has gotten out of bed at 3:00am, the control circuitry 334 can use identified patterns for the user 308 to  
5 determine that the user has only gotten up temporarily (for example, to use the rest room, or get a glass of water) and is not up for the day. By contrast, if the control circuitry 334 identifies that the user 308 has gotten out of the bed 302 at 6:40am, the control circuitry 334 can determine that the user is up for the day and generate a different set of control signals than those that would be generated if it were determined that the user 308 were only getting out of bed temporarily (as would be the case when the user 308 gets out of  
10 the bed 302 at 3:00am). For other users 308, getting out of the bed 302 at 3:00am can be the normal wake-up time, which the control circuitry 334 can learn and respond to accordingly.

[0071] As described above, the control circuitry 334 for the bed 302 can generate control signals for control functions of various other devices. The control signals can be generated, at least in part, based on detected interactions by the user 308 with the bed 302, as well as other information including time, date,  
15 temperature, etc. For example, the control circuitry 334 can communicate with the television 312, receive information from the television 312, and generate control signals for controlling functions of the television 312. For example, the control circuitry 334 can receive an indication from the television 312 that the television 312 is currently on. If the television 312 is located in a different room from the bed 302, the control circuitry 334 can generate a control signal to turn the television 312 off upon making a  
20 determination that the user 308 has gone to bed for the evening. For example, if bed presence of the user 308 on the bed 302 is detected during a particular time range (e.g., between 8:00pm and 7:00am) and persists for longer than a threshold period of time (e.g., 10 minutes) the control circuitry 334 can use this information to determine that the user 308 is in bed for the evening. If the television 312 is on (as indicated by communications received by the control circuitry 334 of the bed 302 from the television 312) the control  
25 circuitry 334 can generate a control signal to turn the television 312 off. The control signals can then be transmitted to the television (e.g., through a directed communication link between the television 312 and the control circuitry 334 or through a network). As another example, rather than turning off the television

312 in response to detection of user bed presence, the control circuitry 334 can generate a control signal that causes the volume of the television 312 to be lowered by a pre-specified amount.

[0072] As another example, upon detecting that the user 308 has left the bed 302 during a specified time range (e.g., between 6:00am and 8:00am) the control circuitry 334 can generate control signals to cause the television 312 to turn on and tune to a pre-specified channel (e.g., the user 308 has indicated a preference for watching the morning news upon getting out of bed in the morning). The control circuitry 334 can generate the control signal and transmit the signal to the television 312 to cause the television 312 to turn on and tune to the desired station (which could be stored at the control circuitry 334, the television 312, or another location). As another example, upon detecting that the user 308 has gotten up for the day, the control circuitry 334 can generate and transmit control signals to cause the television 312 to turn on and begin playing a previously recorded program from a digital video recorder (DVR) in communication with the television 312.

[0073] As another example, if the television 312 is in the same room as the bed 302, the control circuitry 334 does not cause the television 312 to turn off in response to detection of user bed presence.

Rather, the control circuitry 334 can generate and transmit control signals to cause the television 312 to turn off in response to determining that the user 308 is asleep. For example, the control circuitry 334 can monitor biometric signals of the user 308 (e.g., motion, heart rate, respiration rate) to determine that the user 308 has fallen asleep. Upon detecting that the user 308 is sleeping, the control circuitry 334 generates and transmits a control signal to turn the television 312 off. As another example, the control circuitry 334 can generate the control signal to turn off the television 312 after a threshold period of time after the user 308 has fallen asleep (e.g., 10 minutes after the user has fallen asleep). As another example, the control circuitry 334 generates control signals to lower the volume of the television 312 after determining that the user 308 is asleep. As yet another example, the control circuitry 334 generates and transmits a control signal to cause the television to gradually lower in volume over a period of time and then turn off in response to determining that the user 308 is asleep.

[0074] In some implementations, the control circuitry 334 can similarly interact with other media devices, such as computers, tablets, smart phones, stereo systems, etc. For example, upon detecting that the user 308 is asleep, the control circuitry 334 can generate and transmit a control signal to the user

device 310 to cause the user device 310 to turn off, or turn down the volume on a video or audio file being played by the user device 310.

[0075] The control circuitry 334 can additionally communicate with the lighting system 314, receive information from the lighting system 314, and generate control signals for controlling functions of the lighting system 314. For example, upon detecting user bed presence on the bed 302 during a certain time frame (e.g., between 8:00pm and 7:00am) that lasts for longer than a threshold period of time (e.g., 10 minutes) the control circuitry 334 of the bed 302 can determine that the user 308 is in bed for the evening. In response to this determination, the control circuitry 334 can generate control signals to cause lights in one or more rooms other than the room in which the bed 302 is located to switch off. The control signals can then be transmitted to the lighting system 314 and executed by the lighting system 314 to cause the lights in the indicated rooms to shut off. For example, the control circuitry 334 can generate and transmit control signals to turn off lights in all common rooms, but not in other bedrooms. As another example, the control signals generated by the control circuitry 334 can indicate that lights in all rooms other than the room in which the bed 302 is located are to be turned off, while one or more lights located outside of the house containing the bed 302 are to be turned on, in response to determining that the user 308 is in bed for the evening. Additionally, the control circuitry 334 can generate and transmit control signals to cause the nightlight 328 to turn on in response to determining user 308 bed presence or whether the user 308 is asleep. As another example, the control circuitry 334 can generate first control signals for turning off a first set of lights (e.g., lights in common rooms) in response to detecting user bed presence, and second control signals for turning off a second set of lights (e.g., lights in the room in which the bed 302 is located) in response to detecting that the user 308 is asleep.

[0076] In some implementations, in response to determining that the user 308 is in bed for the evening, the control circuitry 334 of the bed 302 can generate control signals to cause the lighting system 314 to implement a sunset lighting scheme in the room in which the bed 302 is located. A sunset lighting scheme can include, for example, dimming the lights (either gradually over time, or all at once) in combination with changing the color of the light in the bedroom environment, such as adding an amber hue to the lighting in the bedroom. The sunset lighting scheme can help to put the user 308 to sleep when the control circuitry 334 has determined that the user 308 is in bed for the evening.

[0077] The control circuitry 334 can also be configured to implement a sunrise lighting scheme when the user 308 wakes up in the morning. The control circuitry 334 can determine that the user 308 is awake for the day, for example, by detecting that the user 308 has gotten off of the bed 302 (i.e., is no longer present on the bed 302) during a specified time frame (e.g., between 6:00am and 8:00am). As another example, the control circuitry 334 can monitor movement, heart rate, respiratory rate, or other biometric signals of the user 308 to determine that the user 308 is awake even though the user 308 has not gotten out of bed. If the control circuitry 334 detects that the user is awake during a specified time frame, the control circuitry 334 can determine that the user 308 is awake for the day. The specified time frame can be, for example, based on previously recorded user bed presence information collected over a period of time (e.g., two weeks) that indicates that the user 308 usually wakes up for the day between 6:30am and 7:30am. In response to the control circuitry 334 determining that the user 308 is awake, the control circuitry 334 can generate control signals to cause the lighting system 314 to implement the sunrise lighting scheme in the bedroom in which the bed 302 is located. The sunrise lighting scheme can include, for example, turning on lights (e.g., the lamp 326, or other lights in the bedroom). The sunrise lighting scheme can further include gradually increasing the level of light in the room where the bed 302 is located (or in one or more other rooms). The sunrise lighting scheme can also include only turning on lights of specified colors. For example, the sunrise lighting scheme can include lighting the bedroom with blue light to gently assist the user 308 in waking up and becoming active.

[0078] In some implementations, the control circuitry 334 can generate different control signals for controlling actions of one or more components, such as the lighting system 314, depending on a time of day that user interactions with the bed 302 are detected. For example, the control circuitry 334 can use historical user interaction information for interactions between the user 308 and the bed 302 to determine that the user 308 usually falls asleep between 10:00pm and 11:00pm and usually wakes up between 6:30am and 7:30am on weekdays. The control circuitry 334 can use this information to generate a first set of control signals for controlling the lighting system 314 if the user 308 is detected as getting out of bed at 3:00am and to generate a second set of control signals for controlling the lighting system 314 if the user 308 is detected as getting out of bed after 6:30am. For example, if the user 308 gets out of bed prior to 6:30am, the control circuitry 334 can turn on lights that guide the user 308's route to a restroom. As

another example, if the user 308 gets out of bed prior to 6:30am, the control circuitry 334 can turn on lights that guide the user 308's route to the kitchen (which can include, for example, turning on the nightlight 328, turning on under bed lighting, or turning on the lamp 326).

[0079] As another example, if the user 308 gets out of bed after 6:30am, the control circuitry 334

5 can generate control signals to cause the lighting system 314 to initiate a sunrise lighting scheme, or to turn on one or more lights in the bedroom and/or other rooms. In some implementations, if the user 308 is detected as getting out of bed prior to a specified morning rise time for the user 308, the control circuitry 334 causes the lighting system 314 to turn on lights that are dimmer than lights that are turned on by the lighting system 314 if the user 308 is detected as getting out of bed after the specified morning rise time.

10 Causing the lighting system 314 to only turn on dim lights when the user 308 gets out of bed during the night (i.e., prior to normal rise time for the user 308) can prevent other occupants of the house from being woken by the lights while still allowing the user 308 to see in order to reach the restroom, kitchen, or another destination within the house.

[0080] The historical user interaction information for interactions between the user 308 and the

15 bed 302 can be used to identify user sleep and awake time frames. For example, user bed presence times and sleep times can be determined for a set period of time (e.g., two weeks, a month, etc.). The control circuitry 334 can then identify a typical time range or time frame in which the user 308 goes to bed, a typical time frame for when the user 308 falls asleep, and a typical time frame for when the user 308 wakes up (and in some cases, different time frames for when the user 308 wakes up and when the user 308

20 actually gets out of bed). In some implementations, buffer time can be added to these time frames. For example, if the user is identified as typically going to bed between 10:00pm and 10:30pm, a buffer of a half hour in each direction can be added to the time frame such that any detection of the user getting onto the bed between 9:30pm and 11:00pm is interpreted as the user 308 going to bed for the evening. As another example, detection of bed presence of the user 308 starting from a half hour before the earliest typical time that the user 308 goes to bed extending until the typical wake up time (e.g., 6:30 am) for the user can be interpreted as the user going to bed for the evening. For example, if the user typically goes to bed between 10:00pm and 10:30pm, if the user's bed presence is sensed at 12:30am one night, that can be interpreted as the user getting into bed for the evening even though this is outside of the user's typical time frame for

going to bed because it has occurred prior to the user's normal wake up time. In some implementations, different time frames are identified for different times of the year (e.g., earlier bed time during winter vs. summer) or at different times of the week (e.g., user wakes up earlier on weekdays than on weekends).

[0081] The control circuitry 334 can distinguish between the user 308 going to bed for an extended period (such as for the night) as opposed to being present on the bed 302 for a shorter period (such as for a nap) by sensing duration of presence of the user 308. In some examples, the control circuitry 334 can distinguish between the user 308 going to bed for an extended period (such as for the night) as opposed to going to bed for a shorter period (such as for a nap) by sensing duration of sleep of the user 308. For example, the control circuitry 334 can set a time threshold whereby if the user 308 is sensed on the bed 302 for longer than the threshold, the user 308 is considered to have gone to bed for the night. In some examples, the threshold can be about 2 hours, whereby if the user 308 is sensed on the bed 302 for greater than 2 hours, the control circuitry 334 registers that as an extended sleep event. In other examples, the threshold can be greater than or less than two hours.

[0082] The control circuitry 334 can detect repeated extended sleep events to determine a typical bed time range of the user 308 automatically, without requiring the user 308 to enter a bed time range. This can allow the control circuitry 334 to accurately estimate when the user 308 is likely to go to bed for an extended sleep event, regardless of whether the user 308 typically goes to bed using a traditional sleep schedule or a non-traditional sleep schedule. The control circuitry 334 can then use knowledge of the bed time range of the user 308 to control one or more components (including components of the bed 302 and/or non-bed peripherals) differently based on sensing bed presence during the bed time range or outside of the bed time range.

[0083] In some examples, the control circuitry 334 can automatically determine the bed time range of the user 308 without requiring user inputs. In some examples, the control circuitry 334 can determine the bed time range of the user 308 automatically and in combination with user inputs. In some examples, the control circuitry 334 can set the bed time range directly according to user inputs. In some examples, the control circuitry 334 can associate different bed times with different days of the week. In each of these examples, the control circuitry 334 can control one or more components (such as the lighting

system 314, the thermostat 316, the security system 318, the oven 322, the coffee maker 324, the lamp 326, and the nightlight 328), as a function of sensed bed presence and the bed time range.

**[0084]** The control circuitry 334 can additionally communicate with the thermostat 316, receive information from the thermostat 316, and generate control signals for controlling functions of the thermostat 316. For example, the user 308 can indicate user preferences for different temperatures at different times, depending on the sleep state or bed presence of the user 308. For example, the user 308 may prefer an environmental temperature of 72 degrees when out of bed, 70 degrees when in bed but awake, and 68 degrees when sleeping. The control circuitry 334 of the bed 302 can detect bed presence of the user 308 in the evening and determine that the user 308 is in bed for the night. In response to this determination, the control circuitry 334 can generate control signals to cause the thermostat to change the temperature to 70 degrees. The control circuitry 334 can then transmit the control signals to the thermostat 316. Upon detecting that the user 308 is in bed during the bed time range or asleep, the control circuitry 334 can generate and transmit control signals to cause the thermostat 316 to change the temperature to 68. The next morning, upon determining that the user is awake for the day (e.g., the user 308 gets out of bed after 6:30am) the control circuitry 334 can generate and transmit control circuitry 334 to cause the thermostat to change the temperature to 72 degrees.

**[0085]** In some implementations, the control circuitry 334 can similarly generate control signals to cause one or more heating or cooling elements on the surface of the bed 302 to change temperature at various times, either in response to user interaction with the bed 302 or at various pre-programmed times. For example, the control circuitry 334 can activate a heating element to raise the temperature of one side of the surface of the bed 302 to 73 degrees when it is detected that the user 308 has fallen asleep. As another example, upon determining that the user 308 is up for the day, the control circuitry 334 can turn off a heating or cooling element. As yet another example, the user 308 can pre-program various times at which the temperature at the surface of the bed should be raised or lowered. For example, the user can program the bed 302 to raise the surface temperature to 76 degrees at 10:00pm, and lower the surface temperature to 68 degrees at 11:30pm.

**[0086]** In some implementations, in response to detecting user bed presence of the user 308 and/or that the user 308 is asleep, the control circuitry 334 can cause the thermostat 316 to change the

temperature in different rooms to different values. For example, in response to determining that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit control signals to cause the thermostat 316 to set the temperature in one or more bedrooms of the house to 72 degrees and set the temperature in other rooms to 67 degrees.

5 [0087] The control circuitry 334 can also receive temperature information from the thermostat 316 and use this temperature information to control functions of the bed 302 or other devices. For example, as discussed above, the control circuitry 334 can adjust temperatures of heating elements included in the bed 302 in response to temperature information received from the thermostat 316.

[0088] In some implementations, the control circuitry 334 can generate and transmit control  
10 signals for controlling other temperature control systems. For example, in response to determining that the user 308 is awake for the day, the control circuitry 334 can generate and transmit control signals for causing floor heating elements to activate. For example, the control circuitry 334 can cause a floor heating system for a master bedroom to turn on in response to determining that the user 308 is awake for the day.

[0089] The control circuitry 334 can additionally communicate with the security system 318,  
15 receive information from the security system 318, and generate control signals for controlling functions of the security system 318. For example, in response to detecting that the user 308 is in bed for the evening, the control circuitry 334 can generate control signals to cause the security system to engage or disengage security functions. The control circuitry 334 can then transmit the control signals to the security system 318 to cause the security system 318 to engage. As another example, the control circuitry 334 can generate  
20 and transmit control signals to cause the security system 318 to disable in response to determining that the user 308 is awake for the day (e.g., user 308 is no longer present on the bed 302 after 6:00am). In some implementations, the control circuitry 334 can generate and transmit a first set of control signals to cause the security system 318 to engage a first set of security features in response to detecting user bed presence of the user 308, and can generate and transmit a second set of control signals to cause the security system  
25 318 to engage a second set of security features in response to detecting that the user 308 has fallen asleep.

[0090] In some implementations, the control circuitry 334 can receive alerts from the security system 318 (and/or a cloud service associated with the security system 318) and indicate the alert to the user 308. For example, the control circuitry 334 can detect that the user 308 is in bed for the evening and

in response, generate and transmit control signals to cause the security system 318 to engage or disengage.

The security system can then detect a security breach (e.g., someone has opened the door 332 without entering the security code, or someone has opened a window when the security system 318 is engaged).

The security system 318 can communicate the security breach to the control circuitry 334 of the bed 302.

5 In response to receiving the communication from the security system 318, the control circuitry 334 can generate control signals to alert the user 308 to the security breach. For example, the control circuitry 334 can cause the bed 302 to vibrate. As another example, the control circuitry 334 can cause portions of the bed 302 to articulate (e.g., cause the head section to raise or lower) in order to wake the user 308 and alert the user to the security breach. As another example, the control circuitry 334 can generate and transmit  
10 control signals to cause the lamp 326 to flash on and off at regular intervals to alert the user 308 to the security breach. As another example, the control circuitry 334 can alert the user 308 of one bed 302 regarding a security breach in a bedroom of another bed, such as an open window in a kid's bedroom. As another example, the control circuitry 334 can send an alert to a garage door controller (e.g., to close and lock the door). As another example, the control circuitry 334 can send an alert for the security to be  
15 disengaged.

[0091] The control circuitry 334 can additionally generate and transmit control signals for controlling the garage door 320 and receive information indicating a state of the garage door 320 (i.e., open or closed). For example, in response to determining that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit a request to a garage door opener or another device capable of  
20 sensing if the garage door 320 is open. The control circuitry 334 can request information on the current state of the garage door 320. If the control circuitry 334 receives a response (e.g., from the garage door opener) indicating that the garage door 320 is open, the control circuitry 334 can either notify the user 308 that the garage door is open, or generate a control signal to cause the garage door opener to close the garage door 320. For example, the control circuitry 334 can send a message to the user device 310 indicating that  
25 the garage door is open. As another example, the control circuitry 334 can cause the bed 302 to vibrate. As yet another example, the control circuitry 334 can generate and transmit a control signal to cause the lighting system 314 to cause one or more lights in the bedroom to flash to alert the user 308 to check the user device 310 for an alert (in this example, an alert regarding the garage door 320 being open).

Alternatively, or additionally, the control circuitry 334 can generate and transmit control signals to cause the garage door opener to close the garage door 320 in response to identifying that the user 308 is in bed for the evening and that the garage door 320 is open. In some implementations, control signals can vary depend on the age of the user 308.

5 [0092] The control circuitry 334 can similarly send and receive communications for controlling or receiving state information associated with the door 332 or the oven 322. For example, upon detecting that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit a request to a device or system for detecting a state of the door 332. Information returned in response to the request can indicate various states for the door 332 such as open, closed but unlocked, or closed and locked. If the door  
10 332 is open or closed but unlocked, the control circuitry 334 can alert the user 308 to the state of the door, such as in a manner described above with reference to the garage door 320. Alternatively, or in addition to alerting the user 308, the control circuitry 334 can generate and transmit control signals to cause the door 332 to lock, or to close and lock. If the door 332 is closed and locked, the control circuitry 334 can determine that no further action is needed.

15 [0093] Similarly, upon detecting that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit a request to the oven 322 to request a state of the oven 322 (e.g., on or off). If the oven 322 is on, the control circuitry 334 can alert the user 308 and/or generate and transmit control signals to cause the oven 322 to turn off. If the oven is already off, the control circuitry 334 can determine that no further action is necessary. In some implementations, different alerts can be generated for different  
20 events. For example, the control circuitry 334 can cause the lamp 326 (or one or more other lights, via the lighting system 314) to flash in a first pattern if the security system 318 has detected a breach, flash in a second pattern if garage door 320 is on, flash in a third pattern if the door 332 is open, flash in a fourth pattern if the oven 322 is on, and flash in a fifth pattern if another bed has detected that a user of that bed has gotten up (e.g., that a child of the user 308 has gotten out of bed in the middle of the night as sensed by  
25 a sensor in the bed 302 of the child). Other examples of alerts that can be processed by the control circuitry 334 of the bed 302 and communicated to the user include a smoke detector detecting smoke (and communicating this detection of smoke to the control circuitry 334), a carbon monoxide tester detecting carbon monoxide, a heater malfunctioning, or an alert from any other device capable of communicating

with the control circuitry 334 and detecting an occurrence that should be brought to the user 308's attention.

[0094] The control circuitry 334 can also communicate with a system or device for controlling a state of the window blinds 330. For example, in response to determining that the user 308 is in bed for the evening, the control circuitry 334 can generate and transmit control signals to cause the window blinds 330 to close. As another example, in response to determining that the user 308 is up for the day (e.g., user has gotten out of bed after 6:30am) the control circuitry 334 can generate and transmit control signals to cause the window blinds 330 to open. By contrast, if the user 308 gets out of bed prior to a normal rise time for the user 308, the control circuitry 334 can determine that the user 308 is not awake for the day and does not generate control signals for causing the window blinds 330 to open. As yet another example, the control circuitry 334 can generate and transmit control signals that cause a first set of blinds to close in response to detecting user bed presence of the user 308 and a second set of blinds to close in response to detecting that the user 308 is asleep.

[0095] The control circuitry 334 can generate and transmit control signals for controlling functions of other household devices in response to detecting user interactions with the bed 302. For example, in response to determining that the user 308 is awake for the day, the control circuitry 334 can generate and transmit control signals to the coffee maker 324 to cause the coffee maker 324 to begin brewing coffee. As another example, the control circuitry 334 can generate and transmit control signals to the oven 322 to cause the oven to begin preheating (for users that like fresh baked bread in the morning). As another example, the control circuitry 334 can use information indicating that the user 308 is awake for the day along with information indicating that the time of year is currently winter and/or that the outside temperature is below a threshold value to generate and transmit control signals to cause a car engine block heater to turn on.

[0096] As another example, the control circuitry 334 can generate and transmit control signals to cause one or more devices to enter a sleep mode in response to detecting user bed presence of the user 308, or in response to detecting that the user 308 is asleep. For example, the control circuitry 334 can generate control signals to cause a mobile phone of the user 308 to switch into sleep mode. The control circuitry 334 can then transmit the control signals to the mobile phone. Later, upon determining that the user 308 is

up for the day, the control circuitry 334 can generate and transmit control signals to cause the mobile phone to switch out of sleep mode.

[0097] In some implementations, the control circuitry 334 can communicate with one or more noise control devices. For example, upon determining that the user 308 is in bed for the evening, or that the user 308 is asleep, the control circuitry 334 can generate and transmit control signals to cause one or more noise cancelation devices to activate. The noise cancelation devices can, for example, be included as part of the bed 302 or located in the bedroom with the bed 302. As another example, upon determining that the user 308 is in bed for the evening or that the user 308 is asleep, the control circuitry 334 can generate and transmit control signals to turn the volume on, off, up, or down, for one or more sound generating devices, such as a stereo system radio, computer, tablet, etc.

[0098] Additionally, functions of the bed 302 are controlled by the control circuitry 334 in response to user interactions with the bed 302. For example, the bed 302 can include an adjustable foundation and an articulation controller configured to adjust the position of one or more portions of the bed 302 by adjusting the adjustable foundation that supports the bed. For example, the articulation controller can adjust the bed 302 from a flat position to a position in which a head portion of a mattress of the bed 302 is inclined upward (e.g., to facilitate a user sitting up in bed and/or watching television). In some implementations, the bed 302 includes multiple separately articulable sections. For example, portions of the bed corresponding to the locations of the air chambers 306a and 306b can be articulated independently from each other, to allow one person positioned on the bed 302 surface to rest in a first position (e.g., a flat position) while a second person rests in a second position (e.g., a reclining position with the head raised at an angle from the waist). In some implementations, separate positions can be set for two different beds (e.g., two twin beds placed next to each other). The foundation of the bed 302 can include more than one zone that can be independently adjusted. The articulation controller can also be configured to provide different levels of massage to one or more users on the bed 302 or to cause the bed to vibrate to communicate alerts to the user 308 as described above.

[0099] The control circuitry 334 can adjust positions (e.g., incline and decline positions for the user 308 and/or an additional user of the bed 302) in response to user interactions with the bed 302. For example, the control circuitry 334 can cause the articulation controller to adjust the bed 302 to a first

recline position for the user 308 in response to sensing user bed presence for the user 308. The control circuitry 334 can cause the articulation controller to adjust the bed 302 to a second recline position (e.g., a less reclined, or flat position) in response to determining that the user 308 is asleep. As another example, the control circuitry 334 can receive a communication from the television 312 indicating that the user 308 has turned off the television 312, and in response the control circuitry 334 can cause the articulation controller to adjust the position of the bed 302 to a preferred user sleeping position (e.g., due to the user turning off the television 312 while the user 308 is in bed indicating that the user 308 wishes to go to sleep).

**[00100]** In some implementations, the control circuitry 334 can control the articulation controller so as to wake up one user of the bed 302 without waking another user of the bed 302. For example, the user 308 and a second user of the bed 302 can each set distinct wakeup times (e.g., 6:30am and 7:15am respectively). When the wakeup time for the user 308 is reached, the control circuitry 334 can cause the articulation controller to vibrate or change the position of only a side of the bed on which the user 308 is located to wake the user 308 without disturbing the second user. When the wakeup time for the second user is reached, the control circuitry 334 can cause the articulation controller to vibrate or change the position of only the side of the bed on which the second user is located. Alternatively, when the second wakeup time occurs, the control circuitry 334 can utilize other methods (such as audio alarms, or turning on the lights) to wake the second user since the user 308 is already awake and therefore will not be disturbed when the control circuitry 334 attempts to wake the second user.

**[00101]** Still referring to FIG. 3, the control circuitry 334 for the bed 302 can utilize information for interactions with the bed 302 by multiple users to generate control signals for controlling functions of various other devices. For example, the control circuitry 334 can wait to generate control signals for, for example, engaging the security system 318, or instructing the lighting system 314 to turn off lights in various rooms until both the user 308 and a second user are detected as being present on the bed 302. As another example, the control circuitry 334 can generate a first set of control signals to cause the lighting system 314 to turn off a first set of lights upon detecting bed presence of the user 308 and generate a second set of control signals for turning off a second set of lights in response to detecting bed presence of a second user. As another example, the control circuitry 334 can wait until it has been determined that both the user 308 and a second user are awake for the day before generating control signals to open the window blinds

330. As yet another example, in response to determining that the user 308 has left the bed and is awake for the day, but that a second user is still sleeping, the control circuitry 334 can generate and transmit a first set of control signals to cause the coffee maker 324 to begin brewing coffee, to cause the security system 318 to deactivate, to turn on the lamp 326, to turn off the nightlight 328, to cause the thermostat 316 to raise the temperature in one or more rooms to 72 degrees, and to open blinds (e.g., the window blinds 330) in rooms other than the bedroom in which the bed 302 is located. Later, in response to detecting that the second user is no longer present on the bed (or that the second user is awake) the control circuitry 334 can generate and transmit a second set of control signals to, for example, cause the lighting system 314 to turn on one or more lights in the bedroom, to cause window blinds in the bedroom to open, and to turn on the television 312 to a pre-specified channel.

**[00102] Examples of Data Processing Systems Associated with a Bed**

**[00103]** Described here are examples of systems and components that can be used for data processing tasks that are, for example, associated with a bed. In some cases, multiple examples of a particular component or group of components are presented. Some of these examples are redundant and/or mutually exclusive alternatives. Connections between components are shown as examples to illustrate possible network configurations for allowing communication between components. Different formats of connections can be used as technically needed or desired. The connections generally indicate a logical connection that can be created with any technologically feasible format. For example, a network on a motherboard can be created with a printed circuit board, wireless data connections, and/or other types of network connections. Some logical connections are not shown for clarity. For example, connections with power supplies and/or computer readable memory may not be shown for clarity sake, as many or all elements of a particular component may need to be connected to the power supplies and/or computer readable memory.

**[00104]** FIG. 4A is a block diagram of an example of a data processing system 400 that can be associated with a bed system, including those described above with respect to FIGS. 1-3. This system 400 includes a pump motherboard 402 and a pump daughterboard 404. The system 400 includes a sensor array 406 that can include one or more sensors configured to sense physical phenomenon of the environment and/or bed, and to report such sensing back to the pump motherboard 402 for, for example, analysis. The

system 400 also includes a controller array 408 that can include one or more controllers configured to control logic-controlled devices of the bed and/or environment. The pump motherboard 400 can be in communication with one or more computing devices 414 and one or more cloud services 410 over local networks, the Internet 412, or otherwise as is technically appropriate. Each of these components will be described in more detail, some with multiple example configurations, below.

**[00105]** In this example, a pump motherboard 402 and a pump daughterboard 404 are communicably coupled. They can be conceptually described as a center or hub of the system 400, with the other components conceptually described as spokes of the system 400. In some configurations, this can mean that each of the spoke components communicates primarily or exclusively with the pump motherboard 402. For example, a sensor of the sensor array may not be configured to, or may not be able to, communicate directly with a corresponding controller. Instead, each spoke component can communicate with the motherboard 402. The sensor of the sensor array 406 can report a sensor reading to the motherboard 402, and the motherboard 402 can determine that, in response, a controller of the controller array 408 should adjust some parameters of a logic controlled device or otherwise modify a state of one or more peripheral devices. In one case, if the temperature of the bed is determined to be too hot, the pump motherboard 402 can determine that a temperature controller should cool the bed.

**[00106]** One advantage of a hub-and-spoke network configuration, sometimes also referred to as a star-shaped network, is a reduction in network traffic compared to, for example, a mesh network with dynamic routing. If a particular sensor generates a large, continuous stream of traffic, that traffic may only be transmitted over one spoke of the network to the motherboard 402. The motherboard 402 can, for example, marshal that data and condense it to a smaller data format for retransmission for storage in a cloud service 410. Additionally or alternatively, the motherboard 402 can generate a single, small, command message to be sent down a different spoke of the network in response to the large stream. For example, if the large stream of data is a pressure reading that is transmitted from the sensor array 406 a few times a second, the motherboard 402 can respond with a single command message to the controller array to increase the pressure in an air chamber. In this case, the single command message can be orders of magnitude smaller than the stream of pressure readings.

[00107] As another advantage, a hub-and-spoke network configuration can allow for an extensible network that can accommodate components being added, removed, failing, etc. This can allow, for example, more, fewer, or different sensors in the sensor array 406, controllers in the controller array 408, computing devices 414, and/or cloud services 410. For example, if a particular sensor fails or is deprecated by a newer version of the sensor, the system 400 can be configured such that only the motherboard 402 needs to be updated about the replacement sensor. This can allow, for example, product differentiation where the same motherboard 402 can support an entry level product with fewer sensors and controllers, a higher value product with more sensors and controllers, and customer personalization where a customer can add their own selected components to the system 400.

[00108] Additionally, a line of air bed products can use the system 400 with different components. In an application in which every air bed in the product line includes both a central logic unit and a pump, the motherboard 402 (and optionally the daughterboard 404) can be designed to fit within a single, universal housing. Then, for each upgrade of the product in the product line, additional sensors, controllers, cloud services, etc., can be added. Design, manufacturing, and testing time can be reduced by designing all products in a product line from this base, compared to a product line in which each product has a bespoke logic control system.

[00109] Each of the components discussed above can be realized in a wide variety of technologies and configurations. Below, some examples of each component will be further discussed. In some alternatives, two or more of the components of the system 400 can be realized in a single alternative component; some components can be realized in multiple, separate components; and/or some functionality can be provided by different components.

[00110] FIG. 4B is a block diagram showing some communication paths of the data processing system 400. As previously described, the motherboard 402 and the pump daughterboard 404 may act as a hub for peripheral devices and cloud services of the system 400. In cases in which the pump daughterboard 404 communicates with cloud services or other components, communications from the pump daughterboard 404 may be routed through the pump motherboard 402. This may allow, for example, the bed to have only a single connection with the internet 412. The computing device 414 may also have a

connection to the internet 412, possibly through the same gateway used by the bed and/or possibly through a different gateway (e.g., a cell service provider).

[00111] Previously, a number of cloud services 410 were described. As shown in FIG 4B, some cloud services, such as cloud services 410d and 410e, may be configured such that the pump motherboard 402 can communicate with the cloud service directly – that is the motherboard 402 may communicate with a cloud service 410 without having to use another cloud service 410 as an intermediary. Additionally or alternatively, some cloud services 410, for example cloud service 410f, may only be reachable by the pump motherboard 402 through an intermediary cloud service, for example cloud service 410e. While not shown here, some cloud services 410 may be reachable either directly or indirectly by the pump motherboard 402.

[00112] Additionally, some or all of the cloud services 410 may be configured to communicate with other cloud services. This communication may include the transfer of data and/or remote function calls according to any technologically appropriate format. For example, one cloud service 410 may request a copy for another cloud service's 410 data, for example, for purposes of backup, coordination, migration, or for performance of calculations or data mining. In another example, many cloud services 410 may contain data that is indexed according to specific users tracked by the user account cloud 410c and/or the bed data cloud 410a. These cloud services 410 may communicate with the user account cloud 410c and/or the bed data cloud 410a when accessing data specific to a particular user or bed.

[00113] FIG. 5 is a block diagram of an example of a motherboard 402 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, compared to other examples described below, this motherboard 402 consists of relatively fewer parts and can be limited to provide a relatively limited feature set.

[00114] The motherboard includes a power supply 500, a processor 502, and computer memory 512. In general, the power supply includes hardware used to receive electrical power from an outside source and supply it to components of the motherboard 402. The power supply can include, for example, a battery pack and/or wall outlet adapter, an AC to DC converter, a DC to AC converter, a power conditioner, a capacitor bank, and/or one or more interfaces for providing power in the current type, voltage, etc., needed by other components of the motherboard 402.

[00115] The processor 502 is generally a device for receiving input, performing logical determinations, and providing output. The processor 502 can be a central processing unit, a microprocessor, general purpose logic circuitry, application-specific integrated circuitry, a combination of these, and/or other hardware for performing the functionality needed.

5 [00116] The memory 512 is generally one or more devices for storing data. The memory 512 can include long term stable data storage (e.g., on a hard disk), short term unstable (e.g., on Random Access Memory) or any other technologically appropriate configuration.

[00117] The motherboard 402 includes a pump controller 504 and a pump motor 506. The pump controller 504 can receive commands from the processor 502 and, in response, control the function of the pump motor 506. For example, the pump controller 504 can receive, from the processor 502, a command to increase the pressure of an air chamber by 0.3 pounds per square inch (PSI). The pump controller 504, in response, engages a valve so that the pump motor 506 is configured to pump air into the selected air chamber, and can engage the pump motor 506 for a length of time that corresponds to 0.3 PSI or until a sensor indicates that pressure has been increased by 0.3 PSI. In an alternative configuration, the message can specify that the chamber should be inflated to a target PSI, and the pump controller 504 can engage the pump motor 506 until the target PSI is reached.

[00118] A valve solenoid 508 can control which air chamber a pump is connected to. In some cases, the solenoid 508 can be controlled by the processor 502 directly. In some cases, the solenoid 508 can be controlled by the pump controller 504.

20 [00119] A remote interface 510 of the motherboard 402 can allow the motherboard 402 to communicate with other components of a data processing system. For example, the motherboard 402 can be able to communicate with one or more daughterboards, with peripheral sensors, and/or with peripheral controllers through the remote interface 510. The remote interface 510 can provide any technologically appropriate communication interface, including but not limited to multiple communication interfaces such as WiFi, Bluetooth, and copper wired networks.

[00120] FIG. 6 is a block diagram of an example of a motherboard 402 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to

FIGS. 1-3. Compared to the motherboard 402 described with reference to FIG 5, the motherboard in FIG 6 can contain more components and provide more functionality in some applications.

[00121] In addition to the power supply 500, processor 502, pump controller 504, pump motor 506, and valve solenoid 508, this motherboard 402 is shown with a valve controller 600, a pressure sensor 602, a universal serial bus (USB) stack 604, a WiFi radio 606, a Bluetooth Low Energy (BLE) radio 608, a ZigBee radio 610, a Bluetooth radio 612 and a computer memory 512.

[00122] Similar to the way that the pump controller 504 converts commands from the processor 502 into control signals for the pump motor 506, the valve controller 600 can convert commands from the processor 502 into control signals for the valve solenoid 508. In one example, the processor 502 can issue a command to the valve controller 600 to connect the pump to a particular air chamber out of the group of air chambers in an air bed. The valve controller 600 can control the position of the valve solenoid 508 so that the pump is connected to the indicated air chamber.

[00123] The pressure sensor 602 can read pressure readings from one or more air chambers of the air bed. The pressure sensor 602 can also preform digital sensor conditioning.

[00124] The motherboard 402 can include a suite of network interfaces, including but not limited to those shown here. These network interfaces can allow the motherboard to communicate over a wired or wireless network with any number of devices, including but not limited to peripheral sensors, peripheral controllers, computing devices, and devices and services connected to the Internet 412.

[00125] FIG. 7 is a block diagram of an example of a daughterboard 404 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In some configurations, one or more daughterboards 404 can be connected to the motherboard 402. Some daughterboards 404 can be designed to offload particular and/or compartmentalized tasks from the motherboard 402. This can be advantageous, for example, if the particular tasks are computationally intensive, proprietary, or subject to future revisions. For example, the daughterboard 404 can be used to calculate a particular sleep data metric. This metric can be computationally intensive, and calculating the sleep metric on the daughterboard 404 can free up the resources of the motherboard 402 while the metric is being calculated. Additionally and/or alternatively, the sleep metric can be subject to future revisions. To update the system 400 with the new sleep metric, it is possible that only the daughterboard 404 that

calculates that metric need be replaced. In this case, the same motherboard 402 and other components can be used, saving the need to perform unit testing of additional components instead of just the daughterboard 404.

[00126] The daughterboard 404 is shown with a power supply 700, a processor 702, computer  
5 readable memory 704, a pressure sensor 706, and a WiFi radio 708. The processor can use the pressure sensor 706 to gather information about the pressure of the air chamber or chambers of an air bed. From this data, the processor 702 can perform an algorithm to calculate a sleep metric. In some examples, the sleep metric can be calculated from only the pressure of air chambers. In other examples, the sleep metric can be calculated from one or more other sensors. In an example in which different data is needed, the processor  
10 702 can receive that data from an appropriate sensor or sensors. These sensors can be internal to the daughterboard 404, accessible via the WiFi radio 708, or otherwise in communication with the processor 702. Once the sleep metric is calculated, the processor 702 can report that sleep metric to, for example, the motherboard 402.

[00127] FIG. 8 is a block diagram of an example of a motherboard 800 with no daughterboard that  
15 can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the motherboard 800 can perform most, all, or more of the features described with reference to the motherboard 402 in FIG. 6 and the daughterboard 404 in FIG. 7.

[00128] FIG. 9 is a block diagram of an example of a sensory array 406 that can be used in a data  
20 processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In general, the sensor array 406 is a conceptual grouping of some or all the peripheral sensors that communicate with the motherboard 402 but are not native to the motherboard 402.

[00129] The peripheral sensors of the sensor array 406 can communicate with the motherboard  
402 through one or more of the network interfaces of the motherboard, including but not limited to the USB stack 1112, a WiFi radio 606, a Bluetooth Low Energy (BLE) radio 608, a ZigBee radio 610, and a  
25 Bluetooth radio 612, as is appropriate for the configuration of the particular sensor. For example, a sensor that outputs a reading over a USB cable can communicate through the USB stack 1112.

[00130] Some of the peripheral sensors 900 of the sensor array 406 can be bed mounted 900. These sensors can be, for example, embedded into the structure of a bed and sold with the bed, or later

affixed to the structure of the bed. Other peripheral sensors 902 and 904 can be in communication with the motherboard 402, but optionally not mounted to the bed. In some cases, some or all of the bed mounted sensors 900 and/or peripheral sensors 902 and 904 can share networking hardware, including a conduit that contains wires from each sensor, a multi-wire cable or plug that, when affixed to the motherboard 402, connect all of the associated sensors with the motherboard 402. In some embodiments, one, some, or all of sensors 902, 904, 906, 908, and 910 can sense one or more features of a mattress, such as pressure, temperature, light, sound, and/or one or more other features of the mattress. In some embodiments, one, some, or all of sensors 902, 904, 906, 908, and 910 can sense one or more features external to the mattress. In some embodiments, pressure sensor 902 can sense pressure of the mattress while some or all of sensors 902, 904, 906, 908, and 910 can sense one or more features of the mattress and/or external to the mattress.

[00131] FIG. 10 is a block diagram of an example of a controller array 408 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In general, the controller array 408 is a conceptual grouping of some or all peripheral controllers that communicate with the motherboard 402 but are not native to the motherboard 402.

[00132] The peripheral controllers of the controller array 408 can communicate with the motherboard 402 through one or more of the network interfaces of the motherboard, including but not limited to the USB stack 1112, a WiFi radio 1114, a Bluetooth Low Energy (BLE) radio 1116, a ZigBee radio 610, and a Bluetooth radio 612, as is appropriate for the configuration of the particular sensor. For example, a controller that receives a command over a USB cable can communicate through the USB stack 1112.

[00133] Some of the controllers of the controller array 408 can be bed mounted 1000, including but not limited to a temperature controller 1006, a light controller 1008, and/or a speaker controller 1010. These controllers can be, for example, embedded into the structure of a bed and sold with the bed, or later affixed to the structure of the bed. Other peripheral controllers 1002 and 1004 can be in communication with the motherboard 402, but optionally not mounted to the bed. In some cases, some or all of the bed mounted controllers 1000 and/or peripheral controllers 1002 and 1004 can share networking hardware, including a conduit that contains wires for each controller, a multi-wire cable or plug that, when affixed to the motherboard 402, connects all of the associated controllers with the motherboard 402.

[00134] FIG. 11 is a block diagram of an example of a computing device 414 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. The computing device 414 can include, for example, computing devices used by a user of a bed. Example computing devices 414 include, but are not limited to, mobile computing devices (e.g., mobile phones, tablet computers, laptops) and desktop computers.

[00135] The computing device 414 includes a power supply 1100, a processor 1102, and computer readable memory 1104. User input and output can be transmitted by, for example, speakers 1106, a touchscreen 1108, or other not shown components such as a pointing device or keyboard. The computing device 414 can run one or more applications 1110. These applications can include, for example, application to allow the user to interact with the system 400. These applications can allow a user to view information about the bed (e.g., sensor readings, sleep metrics), or configure the behavior of the system 400 (e.g., set a desired firmness to the bed, set desired behavior for peripheral devices). In some cases, the computing device 414 can be used in addition to, or to replace, the remote control 122 described previously.

[00136] FIG. 12 is a block diagram of an example bed data cloud service 410a that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the bed data cloud service 410a is configured to collect sensor data and sleep data from a particular bed, and to match the sensor and sleep data with one or more users that use the bed when the sensor and sleep data was generated.

[00137] The bed data cloud service 410a is shown with a network interface 1200, a communication manager 1202, server hardware 1204, and server system software 1206. In addition, the bed data cloud service 410a is shown with a user identification module 1208, a device management 1210 module, a sensor data module 1212, and an advanced sleep data module 1214.

[00138] The network interface 1200 generally includes hardware and low level software used to allow one or more hardware devices to communicate over networks. For example the network interface 1200 can include network cards, routers, modems, and other hardware needed to allow the components of the bed data cloud service 410a to communicate with each other and other destinations over, for example, the Internet 412. The communication manger 1202 generally comprises hardware and software that operate above the network interface 1200. This includes software to initiate, maintain, and tear down network

communications used by the bed data cloud service 410a. This includes, for example, TCP/IP, SSL or TLS, Torrent, and other communication sessions over local or wide area networks. The communication manager 1202 can also provide load balancing and other services to other elements of the bed data cloud service 410a.

5 [00139] The server hardware 1204 generally includes the physical processing devices used to instantiate and maintain bed data cloud service 410a. This hardware includes, but is not limited to processors (e.g., central processing units, ASICs, graphical processors), and computer readable memory (e.g., random access memory, stable hard disks, tape backup). One or more servers can be configured into clusters, multi-computer, or datacenters that can be geographically separate or connected.

10 [00140] The server system software 1206 generally includes software that runs on the server hardware 1204 to provide operating environments to applications and services. The server system software 1206 can include operating systems running on real servers, virtual machines instantiated on real servers to create many virtual servers, server level operations such as data migration, redundancy, and backup.

[00141] The user identification 1208 can include, or reference, data related to users of beds with associated data processing systems. For example, the users can include customers, owners, or other users registered with the bed data cloud service 410a or another service. Each user can have, for example, a unique identifier, user credentials, contact information, billing information, demographic information, or any other technologically appropriate information.

15 [00142] The device manager 1210 can include, or reference, data related to beds or other products associated with data processing systems. For example, the beds can include products sold or registered with a system associated with the bed data cloud service 410a. Each bed can have, for example, a unique identifier, model and/or serial number, sales information, geographic information, delivery information, a listing of associated sensors and control peripherals, etc. Additionally, an index or indexes stored by the bed data cloud service 410a can identify users that are associated with beds. For example, this index can record sales of a bed to a user, users that sleep in a bed, etc.

25 [00143] The sensor data 1212 can record raw or condensed sensor data recorded by beds with associated data processing systems. For example, a bed's data processing system can have a temperature sensor, pressure sensor, and light sensor. Readings from these sensors, either in raw form or in a format

generated from the raw data (e.g. sleep metrics) of the sensors, can be communicated by the bed's data processing system to the bed data cloud service 410a for storage in the sensor data 1212. Additionally, an index or indexes stored by the bed data cloud service 410a can identify users and/or beds that are associated with the sensor data 1212.

5 [00144] The bed data cloud service 410a can use any of its available data to generate advanced sleep data 1214. In general, the advanced sleep data 1214 includes sleep metrics and other data generated from sensor readings. Some of these calculations can be performed in the bed data cloud service 410a instead of locally on the bed's data processing system, for example, because the calculations are computationally complex or require a large amount of memory space or processor power that is not  
10 available on the bed's data processing system. This can help allow a bed system to operate with a relatively simple controller and still be part of a system that performs relatively complex tasks and computations.

[00145] FIG. 13 is a block diagram of an example sleep data cloud service 410b that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the sleep data cloud service 410b is configured to record data related  
15 to users' sleep experience.

[00146] The sleep data cloud service 410b is shown with a network interface 1300, a communication manager 1302, server hardware 1304, and server system software 1306. In addition, the sleep data cloud service 410b is shown with a user identification module 1308, a pressure sensor manager 1310, a pressure based sleep data module 1312, a raw pressure sensor data module 1314, and a non-  
20 pressure sleep data module 1316.

[00147] The pressure sensor manager 1310 can include, or reference, data related to the configuration and operation of pressure sensors in beds. For example, this data can include an identifier of the types of sensors in a particular bed, their settings and calibration data, etc.

[00148] The pressure based sleep data 1312 can use raw pressure sensor data 1314 to calculate  
25 sleep metrics specifically tied to pressure sensor data. For example, user presence, movements, weight change, heart rate, and breathing rate can all be determined from raw pressure sensor data 1314. Additionally, an index or indexes stored by the sleep data cloud service 410b can identify users that are associated with pressure sensors, raw pressure sensor data, and/or pressure based sleep data.

[00149] The non-pressure sleep data 1316 can use other sources of data to calculate sleep metrics. For example, user entered preferences, light sensor readings, and sound sensor readings can all be used to track sleep data. Additionally, an index or indexes stored by the sleep data cloud service 410b can identify users that are associated with other sensors and/or non-pressure sleep data 1316.

5 [00150] FIG. 14 is a block diagram of an example user account cloud service 410c that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the user account cloud service 410c is configured to record a list of users and to identify other data related to those users.

[00151] The user account cloud service 410c is shown with a network interface 1400, a  
10 communication manager 1402, server hardware 1404, and server system software 1406. In addition, the user account cloud service 410c is shown with a user identification module 1408, a purchase history module 1410, an engagement module 1412, and an application usage history module 1414.

[00152] The user identification module 1408 can include, or reference, data related to users of  
15 beds with associated data processing systems. For example, the users can include customers, owners, or other users registered with the user account cloud service 410a or another service. Each user can have, for example, a unique identifier, and user credentials, demographic information, or any other technologically appropriate information.

[00153] The purchase history module 1410 can include, or reference, data related to purchases by  
20 users. For example, the purchase data can include a sale's contact information, billing information, and salesperson information. Additionally, an index or indexes stored by the user account cloud service 410c can identify users that are associated with a purchase.

[00154] The engagement 1412 can track user interactions with the manufacturer, vendor, and/or  
manager of the bed and or cloud services. This engagement data can include communications (e.g., emails, service calls), data from sales (e.g., sales receipts, configuration logs), and social network interactions.

25 [00155] The usage history module 1414 can contain data about user interactions with one or more applications and/or remote controls of a bed. For example, a monitoring and configuration application can be distributed to run on, for example, computing devices 412. This application can log and report user

interactions for storage in the application usage history module 1414. Additionally, an index or indexes stored by the user account cloud service 410c can identify users that are associated with each log entry.

[00156] FIG. 15 is a block diagram of an example point of sale cloud service 1500 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the point of sale cloud service 1500 is configured to record data  
5 related to users' purchases.

[00157] The point of sale cloud service 1500 is shown with a network interface 1502, a communication manager 1504, server hardware 1506, and server system software 1508. In addition, the point of sale cloud service 1500 is shown with a user identification module 1510, a purchase history  
10 module 1512, and a setup module 1514.

[00158] The purchase history module 1512 can include, or reference, data related to purchases made by users identified in the user identification module 1510. The purchase information can include, for example, data of a sale, price, and location of sale, delivery address, and configuration options selected by the users at the time of sale. These configuration options can include selections made by the user about  
15 how they wish their newly purchased beds to be setup and can include, for example, expected sleep schedule, a listing of peripheral sensors and controllers that they have or will install, etc.

[00159] The bed setup module 1514 can include, or reference, data related to installations of beds that users' purchase. The bed setup data can include, for example, the date and address to which a bed is delivered, the person that accepts delivery, the configuration that is applied to the bed upon delivery, the  
20 name or names of the person or people who will sleep on the bed, which side of the bed each person will use, etc.

[00160] Data recorded in the point of sale cloud service 1500 can be referenced by a user's bed system at later dates to control functionality of the bed system and/or to send control signals to peripheral components according to data recorded in the point of sale cloud service 1500. This can allow a  
25 salesperson to collect information from the user at the point of sale that later facilitates automation of the bed system. In some examples, some or all aspects of the bed system can be automated with little or no user-entered data required after the point of sale. In other examples, data recorded in the point of sale cloud service 1500 can be used in connection with a variety of additional data gathered from user-entered data.

[00161] FIG. 16 is a block diagram of an example environment cloud service 1600 that can be used in a data processing system that can be associated with a bed system, including those described above with respect to FIGS. 1-3. In this example, the environment cloud service 1600 is configured to record data related to users' home environment.

5 [00162] The environment cloud service 1600 is shown with a network interface 1602, a communication manager 1604, server hardware 1606, and server system software 1608. In addition, the environment cloud service 1600 is shown with a user identification module 1610, an environmental sensor module 1612, and an environmental factors module 1614.

[00163] The environmental sensors module 1612 can include a listing of sensors that users' in the  
10 user identification module 1610 have installed in their bed. These sensors include any sensors that can detect environmental variables – light sensors, noise sensors, vibration sensors, thermostats, etc. Additionally, the environmental sensors module 1612 can store historical readings or reports from those sensors.

[00164] The environmental factors module 1614 can include reports generated based on data in  
15 the environmental sensors module 1612. For example, for a user with a light sensor with data in the environment sensors module 1612, the environmental factors module 1614 can hold a report indicating the frequency and duration of instances of increased lighting when the user is asleep.

[00165] In the examples discussed here, each cloud service 410 is shown with some of the same components. In various configurations, these same components can be partially or wholly shared between  
20 services, or they can be separate. In some configurations, each service can have separate copies of some or all of the components that are the same or different in some ways. Additionally, these components are only supplied as illustrative examples. In other examples each cloud service can have different number, types, and styles of components that are technically possible.

[00166] FIG. 17 is a block diagram of an example of using a data processing system that can be  
25 associated with a bed (such as a bed of the bed systems described herein) to automate peripherals around the bed. Shown here is a behavior analysis module 1700 that runs on the pump motherboard 402. For example, the behavior analysis module 1700 can be one or more software components stored on the computer memory 512 and executed by the processor 502. In general, the behavior analysis module 1700

can collect data from a wide variety of sources (e.g., sensors, non-sensor local sources, cloud data services) and use a behavioral algorithm 1702 to generate one or more actions to be taken (e.g., commands to send to peripheral controllers, data to send to cloud services). This can be useful, for example, in tracking user behavior and automating devices in communication with the user's bed.

5 [00167] The behavior analysis module 1700 can collect data from any technologically appropriate source, for example, to gather data about features of a bed, the bed's environment, and/or the bed's users. Some such sources include any of the sensors of the sensor array 406. For example, this data can provide the behavior analysis module 1700 with information about the current state of the environment around the bed. For example, the behavior analysis module 1700 can access readings from the pressure sensor 902 to  
10 determine the pressure of an air chamber in the bed. From this reading, and potentially other data, user presence in the bed can be determined. In another example, the behavior analysis module can access a light sensor 908 to detect the amount of light in the bed's environment.

[00168] Similarly, the behavior analysis module 1700 can access data from cloud services. For example, the behavior analysis module 1700 can access the bed cloud service 410a to access historical  
15 sensor data 1212 and/or advanced sleep data 1214. Other cloud services 410, including those not previously described can be accessed by the behavior analysis module 1700. For example, the behavior analysis module 1700 can access a weather reporting service, a 3<sup>rd</sup> party data provider (e.g., traffic and news data, emergency broadcast data, user travel data), and/or a clock and calendar service.

[00169] Similarly, the behavior analysis module 1700 can access data from non-sensor sources  
20 1704. For example, the behavior analysis module 1700 can access a local clock and calendar service (e.g., a component of the motherboard 402 or of the processor 502).

[00170] The behavior analysis module 1700 can aggregate and prepare this data for use by one or more behavioral algorithms 1702. The behavioral algorithms 1702 can be used to learn a user's behavior and/or to perform some action based on the state of the accessed data and/or the predicted user behavior.  
25 For example, the behavior algorithm 1702 can use available data (e.g., pressure sensor, non-sensor data, clock and calendar data) to create a model of when a user goes to bed every night. Later, the same or a different behavioral algorithm 1702 can be used to determine if an increase in air chamber pressure is likely to indicate a user going to bed and, if so, send some data to a third-party cloud service 410 and/or engage a

device such as a pump controller 504, foundation actuators 1706, temperature controller 1008, under-bed lighting 1010, a peripheral controller 1002, or a peripheral controller 1004, to name a few.

[00171] In the example shown, the behavioral analysis module 1700 and the behavioral algorithm 1702 are shown as components of the motherboard 402. However, other configurations are possible. For example, the same or a similar behavioral analysis module and/or behavior algorithm can be run in one or more cloud services, and the resulting output can be sent to the motherboard 402, a controller in the controller array 408, or to any other technologically appropriate recipient.

[00172] FIG. 18 shows an example of a computing device 1800 and an example of a mobile computing device that can be used to implement the techniques described here. The computing device 1800 is intended to represent various forms of digital computers, such as laptops, desktops, workstations, personal digital assistants, servers, blade servers, mainframes, and other appropriate computers. The mobile computing device is intended to represent various forms of mobile devices, such as personal digital assistants, cellular telephones, smart-phones, and other similar computing devices. The components shown here, their connections and relationships, and their functions, are meant to be exemplary only, and are not meant to limit implementations of the inventions described and/or claimed in this document.

[00173] The computing device 1800 includes a processor 1802, a memory 1804, a storage device 1806, a high-speed interface 1808 connecting to the memory 1804 and multiple high-speed expansion ports 1810, and a low-speed interface 1812 connecting to a low-speed expansion port 1814 and the storage device 1806. Each of the processor 1802, the memory 1804, the storage device 1806, the high-speed interface 1808, the high-speed expansion ports 1810, and the low-speed interface 1812, are interconnected using various busses, and can be mounted on a common motherboard or in other manners as appropriate. The processor 1802 can process instructions for execution within the computing device 1800, including instructions stored in the memory 1804 or on the storage device 1806 to display graphical information for a GUI on an external input/output device, such as a display 1816 coupled to the high-speed interface 1808. In other implementations, multiple processors and/or multiple buses can be used, as appropriate, along with multiple memories and types of memory. Also, multiple computing devices can be connected, with each device providing portions of the necessary operations (e.g., as a server bank, a group of blade servers, or a multi-processor system).

[00174] The memory 1804 stores information within the computing device 1800. In some implementations, the memory 1804 is a volatile memory unit or units. In some implementations, the memory 1804 is a non-volatile memory unit or units. The memory 1804 can also be another form of computer-readable medium, such as a magnetic or optical disk.

5 [00175] The storage device 1806 is capable of providing mass storage for the computing device 1800. In some implementations, the storage device 1806 can be or contain a computer-readable medium, such as a floppy disk device, a hard disk device, an optical disk device, or a tape device, a flash memory or other similar solid state memory device, or an array of devices, including devices in a storage area network or other configurations. A computer program product can be tangibly embodied in an information carrier.  
10 The computer program product can also contain instructions that, when executed, perform one or more methods, such as those described above. The computer program product can also be tangibly embodied in a computer- or machine-readable medium, such as the memory 1804, the storage device 1806, or memory on the processor 1802.

[00176] The high-speed interface 1808 manages bandwidth-intensive operations for the  
15 computing device 1800, while the low-speed interface 1812 manages lower bandwidth-intensive operations. Such allocation of functions is exemplary only. In some implementations, the high-speed interface 1808 is coupled to the memory 1804, the display 1816 (e.g., through a graphics processor or accelerator), and to the high-speed expansion ports 1810, which can accept various expansion cards (not shown). In the implementation, the low-speed interface 1812 is coupled to the storage device 1806 and the  
20 low-speed expansion port 1814. The low-speed expansion port 1814, which can include various communication ports (e.g., USB, Bluetooth, Ethernet, wireless Ethernet) can be coupled to one or more input/output devices, such as a keyboard, a pointing device, a scanner, or a networking device such as a switch or router, e.g., through a network adapter.

[00177] The computing device 1800 can be implemented in a number of different forms, as  
25 shown in the figure. For example, it can be implemented as a standard server 1820, or multiple times in a group of such servers. In addition, it can be implemented in a personal computer such as a laptop computer 1822. It can also be implemented as part of a rack server system 1824. Alternatively, components from the computing device 1800 can be combined with other components in a mobile device (not shown), such as a

mobile computing device 1850. Each of such devices can contain one or more of the computing device 1800 and the mobile computing device 1850, and an entire system can be made up of multiple computing devices communicating with each other.

[00178] The mobile computing device 1850 includes a processor 1852, a memory 1864, an input/output device such as a display 1854, a communication interface 1866, and a transceiver 1868, among other components. The mobile computing device 1850 can also be provided with a storage device, such as a micro-drive or other device, to provide additional storage. Each of the processor 1852, the memory 1864, the display 1854, the communication interface 1866, and the transceiver 1868, are interconnected using various buses, and several of the components can be mounted on a common motherboard or in other manners as appropriate.

[00179] The processor 1852 can execute instructions within the mobile computing device 1850, including instructions stored in the memory 1864. The processor 1852 can be implemented as a chipset of chips that include separate and multiple analog and digital processors. The processor 1852 can provide, for example, for coordination of the other components of the mobile computing device 1850, such as control of user interfaces, applications run by the mobile computing device 1850, and wireless communication by the mobile computing device 1850.

[00180] The processor 1852 can communicate with a user through a control interface 1858 and a display interface 1856 coupled to the display 1854. The display 1854 can be, for example, a TFT (Thin-Film-Transistor Liquid Crystal Display) display or an OLED (Organic Light Emitting Diode) display, or other appropriate display technology. The display interface 1856 can comprise appropriate circuitry for driving the display 1854 to present graphical and other information to a user. The control interface 1858 can receive commands from a user and convert them for submission to the processor 1852. In addition, an external interface 1862 can provide communication with the processor 1852, so as to enable near area communication of the mobile computing device 1850 with other devices. The external interface 1862 can provide, for example, for wired communication in some implementations, or for wireless communication in other implementations, and multiple interfaces can also be used.

[00181] The memory 1864 stores information within the mobile computing device 1850. The memory 1864 can be implemented as one or more of a computer-readable medium or media, a volatile

memory unit or units, or a non-volatile memory unit or units. An expansion memory 1874 can also be provided and connected to the mobile computing device 1850 through an expansion interface 1872, which can include, for example, a SIMM (Single In Line Memory Module) card interface. The expansion memory 1874 can provide extra storage space for the mobile computing device 1850, or can also store applications or other information for the mobile computing device 1850. Specifically, the expansion memory 1874 can include instructions to carry out or supplement the processes described above, and can include secure information also. Thus, for example, the expansion memory 1874 can be provide as a security module for the mobile computing device 1850, and can be programmed with instructions that permit secure use of the mobile computing device 1850. In addition, secure applications can be provided via the SIMM cards, along with additional information, such as placing identifying information on the SIMM card in a non-hackable manner.

**[00182]** The memory can include, for example, flash memory and/or NVRAM memory (non-volatile random access memory), as discussed below. In some implementations, a computer program product is tangibly embodied in an information carrier. The computer program product contains instructions that, when executed, perform one or more methods, such as those described above. The computer program product can be a computer- or machine-readable medium, such as the memory 1864, the expansion memory 1874, or memory on the processor 1852. In some implementations, the computer program product can be received in a propagated signal, for example, over the transceiver 1868 or the external interface 1862.

**[00183]** The mobile computing device 1850 can communicate wirelessly through the communication interface 1866, which can include digital signal processing circuitry where necessary. The communication interface 1866 can provide for communications under various modes or protocols, such as GSM voice calls (Global System for Mobile communications), SMS (Short Message Service), EMS (Enhanced Messaging Service), or MMS messaging (Multimedia Messaging Service), CDMA (code division multiple access), TDMA (time division multiple access), PDC (Personal Digital Cellular), WCDMA (Wideband Code Division Multiple Access), CDMA2000, or GPRS (General Packet Radio Service), among others. Such communication can occur, for example, through the transceiver 1868 using a radio-frequency. In addition, short-range communication can occur, such as using a Bluetooth, WiFi, or

other such transceiver (not shown). In addition, a GPS (Global Positioning System) receiver module 1870 can provide additional navigation- and location-related wireless data to the mobile computing device 1850, which can be used as appropriate by applications running on the mobile computing device 1850.

[00184] The mobile computing device 1850 can also communicate audibly using an audio codec 1860, which can receive spoken information from a user and convert it to usable digital information. The audio codec 1860 can likewise generate audible sound for a user, such as through a speaker, e.g., in a handset of the mobile computing device 1850. Such sound can include sound from voice telephone calls, can include recorded sound (e.g., voice messages, music files, etc.) and can also include sound generated by applications operating on the mobile computing device 1850.

[00185] The mobile computing device 1850 can be implemented in a number of different forms, as shown in the figure. For example, it can be implemented as a cellular telephone 1880. It can also be implemented as part of a smart-phone 1882, personal digital assistant, or other similar mobile device.

[00186] Various implementations of the systems and techniques described here can be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations can include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which can be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device.

[00187] These computer programs (also known as programs, software, software applications or code) include machine instructions for a programmable processor, and can be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the terms machine-readable medium and computer-readable medium refer to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term machine-readable signal refers to any signal used to provide machine instructions and/or data to a programmable processor.

**[00188]** To provide for interaction with a user, the systems and techniques described here can be implemented on a computer having a display device (e.g., a CRT (cathode ray tube) or LCD (liquid crystal display) monitor) for displaying information to the user and a keyboard and a pointing device (e.g., a mouse or a trackball) by which the user can provide input to the computer. Other kinds of devices can be used to provide for interaction with a user as well; for example, feedback provided to the user can be any form of sensory feedback (e.g., visual feedback, auditory feedback, or tactile feedback); and input from the user can be received in any form, including acoustic, speech, or tactile input.

**[00189]** The systems and techniques described here can be implemented in a computing system that includes a backend component (e.g., as a data server), or that includes a middleware component (e.g., an application server), or that includes a frontend component (e.g., a client computer having a graphical user interface or a Web browser through which a user can interact with an implementation of the systems and techniques described here), or any combination of such backend, middleware, or frontend components. The components of the system can be interconnected by any form or medium of digital data communication (e.g., a communication network). Examples of communication networks include a local area network (LAN), a wide area network (WAN), and the Internet.

**[00190]** The computing system can include clients and servers. A client and server are generally remote from each other and typically interact through a communication network. The relationship of client and server arises by virtue of computer programs running on the respective computers and having a client-server relationship to each other.

**[00191]** FIG. 19 is a block diagram of an example bed system 1900 for determining ambient temperature in an environment surrounding the bed system 1900. The bed system 1900 can include multiple sensors (e.g., refer to FIG. 20) that can detect different types of signals in the environment surrounding the bed system 1900. The sensors of bed system 1900 can detect barometric pressure 1904, sleeper pressure 1906, ambient temperature 1908, and/or sleeper-microclimate temperature 1910. The sensors of the bed system 1900 can be configured to detect any combination of 1904, 1906, 1908, and 1910. For example, the sensors of the bed system 1900 may detect only the barometric pressure 1904 and the ambient temperature 1908, and, using those readings, a controller 1902 can determine an ambient room temperature 1912. Other combinations of 1904, 1906, 1908, and 1910 are also possible. In some

implementations, a single sensor can measure a plurality of different signals. The single sensor can detect features of the atmospheric at and/or around the bed system 1900, such as gas composition in the atmosphere, pressure, temperature, and humidity signals. The sensors described herein can be integrated into or otherwise attached to the bed system 1900. Any of the sensors described herein can also be mounted on a bed frame of the bed system 1900, in a pump housing of the bed system 1900, in an HVAC system of a home where the bed system 1900 is located, or anywhere else that is appropriate to mount the sensors.

[00192] The bed system 1900 can also be in communication (e.g., wired, wireless, BLUETOOTH, WIFI, etc.) with the controller 1902 via one or more network(s). The controller 1902 can be similar to, e.g., controllers described above. The controller 1902 can be configured to adjust settings of the bed system 1900. The controller 1902 can have one or more processors and can be configured to perform one or more operations described in this document, such as determining an ambient room temperature 1912. Thus, the controller 1902 can receive the detected barometric pressure 1904, sleeper pressure 1906, ambient temperature 1908, and/or sleeper microclimate temperature 1910 from the sensors of the bed system 1900. Using 1904, 1906, 1908, and/or 1910, the controller 1920 can determine the ambient room temperature 1912 (e.g., refer to FIG 21).

[00193] The controller 1902 can also be in communication (e.g., wired, wireless, BLUETOOTH, WIFI, etc.) with an automation controller 1914 via the one or more network(s). The automation controller 1914 can have one or more processors and can be configured to initiate one or more home automation events (e.g., instructing a thermostat to adjust the ambient temperature) based on the ambient room temperature 1912.

[00194] The controller 1902 can, for example, determine one or more home automation events that can be made by the automation controller 1914 based on the ambient room temperature 1912. The controller 1902 can then transmit the determined home automation events to the automation controller 1914. The automation controller 1914 can perform or otherwise initiate the received home automation events. In some implementations, the automation controller 1914 can determine and perform or otherwise initiate the home automation events instead of the controller 1902. In some implementations, the controller 1902 and the automation controller 1914 can be a same controller, control unit, component, computing system, computing device, and/or server.

[00195] The home automation events include a variety of changes that can be made to the environment surrounding the bed system 1900. For example, a home automation event can include adjusting a temperature in the environment, such as a room where the bed system 1900 is located. The automation controller 1914 can be configured to activate or otherwise turn on an HVAC in a house where  
5 the bed system 1900 is located to lower (or alternatively raise) a temperature in the room of the bed system 1900. Once the HVAC is activated, the sensors of the bed system 1900 can continuously detect the signals 1904, 1906, 1908, and/or 1910 and transmit those signals to the controller 1902. The controller 1902 can determine whether the ambient room temperature 1912 has lowered based on the signals 1904, 1906, 1908, and/or 1910. Once the ambient room temperature 1912 lowers to or below a predetermined threshold level,  
10 the controller 1902 can instruct the automation controller 1914 to perform another home automation event, such as turning off the HVAC in the house. Automatically adjusting the temperature of the room where the bed system 1900 is located can be beneficial to ensure that users continue to sleep uninterrupted and comfortably through the night in one or more preferred environmental conditions.

[00196] One or more other home automation events are possible. An example home automation  
15 event includes actuating a heating or cooling element of the bed system 1900. Another home automation event includes turning off the heating or cooling element of the bed system 1900. Thus, a temperature on a surface of the bed system 1900 (e.g., a microclimate of the bed system 1900) can be adjusted based on the ambient room temperature 1912. Automatically adjusting the microclimate of the bed system 1900 can be beneficial to ensure that users continue to sleep uninterrupted and comfortably through the night in one or  
20 more preferred environmental conditions.

[00197] Another home automation event can include adjusting pressure (e.g., firmness) settings of the bed system 1900. Yet another home automation event can include adjusting a position of one or more portions of the bed system 1900, such as inclining a head portion of the bed system 1900 and declining a foot portion of the bed system 1900.

25 [00198] FIG. 20 is a block diagram of components of the example bed system 1900 that can be used to determine ambient temperature in the environment surrounding the bed system 1900.

[00199] The bed system 1900 can include an air bladder 2000. Sometimes, the bed system 1900 can include multiple air bladders, for example, in different regions of the bed system 1900. The air bladder

2000, as described throughout this disclosure, can retain a certain amount of air 2008 that corresponds to one or more pressure (e.g., firmness) settings that are set for the bed system 1900.

[00200] A bladder pressure sensor 2002 can be configured to detect pressure within and/or outside of the air bladder 2000. For example, the sleeper pressure 1906 can be applied to the air bladder 2000. The  
5 bladder pressure sensor 2002 can sense the sleeper pressure 1906 applied to the air bladder 2000 and transmit the sleeper pressure 1906 readings to the controller 1902.

[00201] The bladder pressure sensor 2002 can also be in fluid communication with the air bladder 2000. The bladder pressure sensor 2002 can be positioned within the air bladder 2000. Sometimes, the  
10 bladder pressure sensor 2002 can be part of the controller 1902. Bladder pressure values (e.g., the sleeper pressure 1906) that are sensed by the bladder pressure sensor 2002 can then be transmitted to the controller 1902.

[00202] The bed system 1900 can also include a barometric sensor 2004. The barometric sensor 2004 can be configured to detect the barometric pressure 1904 that both pushes against the air bladder 2000 and also the barometric sensor 2004 of the mattress system 1900. The barometric pressure 1904 can push  
15 against the air bladder 2000 and the barometric sensor 2004 at a same time. An amount of barometric pressure 1904 that is sensed can depend on pressure in the atmosphere and can increase or decrease based on changes in weather patterns and/or ambient temperature. Sometimes, the barometric sensor 2004 is also a temperature sensor that can also detect the ambient temperature 1908 depicted in FIG 19.

[00203] The bed system 1900 can also include a microclimate temperature sensor 2006. The  
20 microclimate temperature sensor 2006 can detect the sleeper microclimate temperature 1910. For example, the microclimate temperature sensor 2006 can be attached to a pad that overlays a portion of a top surface of the bed system 1900. As the user sleeps or lays on the top surface of the bed system 1900, the microclimate temperature sensor 2006 can detect temperature values at the top surface of the bed system 1900. These temperature values can result from a body temperature of the user, from heat from the  
25 environment, etc. Increased temperature values can also, for example, cause increased pressure on the air bladder 2000, and this increase in pressure can be detected by the bladder pressure sensor 2002. Moreover, the sum of of the barometric pressure 1904, the sleeper pressure 1906, the ambient temperature 1908, and the sleeper microclimate temperature 1910 can cause pressure changes on the air bladder 2000, all of which

can be detected by the bladder pressure sensor 2002 as a single net pressure and be transmitted to the controller 1902 for further processing.

[00204] Multiple microclimate temperature sensors can be positioned and used in the bed system 1900 to detect temperatures at different areas of the top surface of the bed system 1900. The sleeper  
5 microclimate temperature 1910 detected by the microclimate temperature sensor 2006 can be transmitted to the controller 1902. Sometimes, the microclimate temperature sensor 2006 can also detect the ambient temperature 1908.

[00205] Any of the sensors 2002, 2004, and 2006 can be integrated into or otherwise part of the bed system 1900. Any of the sensors 2002, 2004, and 2006 can also be separate from the bed system 1900  
10 and in communication (e.g., wired and/or wireless) with the controller 1902. As an illustrative example, the barometric sensor 2004 can be attached to a bed frame of the bed system 1900 and the microclimate temperature sensor 2006 can be part of a pad that overlays a top surface of the bed system 1900 that a user sleeps on. One or more other configurations are also possible.

[00206] FIG. 21 is a swimlane diagram of an example process 2100 for initiating a home  
15 automation event based on determining ambient temperature in an environment surrounding the example bed system of FIG. 19. For clarity, the process 2100 is being described with reference to components of the bed system 1900. However, other system or systems can be used to perform the same or a similar process.

[00207] The process 2100 can begin, for example, when the bladder pressure sensor 2002 senses bladder pressure inside an air bladder of the bed system at a particular time (2102). The bladder pressure  
20 sensor 2002 can be fluidically coupled to the air bladder of the bed system, as described in reference to FIG. 20. The particular time can be at predetermined time intervals. For example, every 1, 2, 3, 4, 5 seconds, minutes or hours etc. the bladder pressure sensor 2002 can detect or sense the bladder pressure inside the air bladder. Sometimes, the bladder pressure sensor 2002 can continuously sense the bladder pressure inside the air bladder. The bladder pressure sensor 2002 then transmits bladder pressure readings to the  
25 controller 1902 (2104).

[00208] The barometric sensor 2004 senses barometric pressure of an ambient environment surrounding the bed system for the particular time (2106). The barometric sensor 2004 can be located in the ambient environment outside of the bed system. Sometimes, the barometric sensor 2004 can be attached to

or otherwise integrated with one or more components of the bed system, such as a mattress, a controller for a pump, or a frame of a foundation under the mattress. The barometric pressure sensor 2004 detects or otherwise senses the barometric pressure surrounding the bed system at a same time as the bladder pressure sensor 2002 detects or senses the bladder pressure inside the air chamber. The barometric pressure sensor 2004 then transmits barometric pressure readings to the controller 1902 (2108).

**[00209]** The microclimate temperature sensor 2006 senses microclimate temperature in a microclimate around a sleeper of the bed system for the particular time (2110). The microclimate temperature sensor 2006 can be any type of temperature sensor that is positioned in the ambient environment and near the bed system or otherwise configured to/integrated with the bed system (e.g., refer to FIG. 20). The microclimate temperature sensor 2006 can detect or otherwise sense the microclimate temperature in the microclimate around the sleeper at the same time as the bladder pressure sensor 2002 senses the bladder pressure inside an air bladder and the barometric sensor 2004 senses the barometric pressure of the ambient environment. The microclimate temperature sensor 2006 then transmits microclimate temperature readings to the controller 1902 (2112). In some implementations, the microclimate temperature sensor 2006 may not be part of the bed system and therefore may not provide microclimate temperature readings to the controller 1902. Instead, the controller 1902 may only receive the bladder pressure readings and the barometric pressure readings.

**[00210]** In some implementations, 2102, 2106, and 2110 can be performed at a same time. 2102, 2106, and 2110 can also be performed sequentially or in any other order. As mentioned above, the 2102, 2106, and 2110 can also be continuously performed. Moreover, 2104, 2108, and 2112 can be performed at a same time, sequentially, or in any other order. As an example, each of the sensors 2002, 2004, and 2006 can sense readings in 2102, 2106, and 2110 at a same time then transmit the readings to the controller 1902 in 2104, 2108, and 2112 at a same time that is different or later than the time that the readings are sensed in 2102, 2106, and 2110.

**[00211]** The controller 1902 receives the readings from the sensors 2002, 2004, and 2006 in 2114. As mentioned above, the controller 1902 can receive the readings some time after the readings are detected in 2102, 2106, and/or 2110. The controller 1902 can receive all the readings at once. The controller 1902 can also receive the readings in real time as they are detected and transmitted to the controller 1902.

[00212] The controller 1902 provides the readings as input to an ambient temperature classifier (2116). The controller 1902 can provide all the readings as input. Sometimes, the controller 1902 can provide a proper subset of the readings as input. The proper subset can include some but not all of the readings that are received in 2114. For example, the controller 1902 may provide the bladder pressure readings and the barometric pressure readings as input to the ambient temperature classifier. Other times, the controller 1902 may only provide the microclimate temperature readings as input to the ambient temperature classifier. One or more other combinations of readings are also possible as input.

[00213] The controller 1902 then receives output from the ambient temperature classifier of an ambient temperature value (2118). As mentioned throughout, the ambient temperature value indicates a temperature of a room or environment that surrounds the bed system.

[00214] For example, if the bed is located in a bedroom, the ambient temperature value can indicate a current temperature of the bedroom. The ambient temperature value can be different than other temperature values throughout the home. In other words, an HVAC unit may have a thermostat in a portion of the home that does not reflect an actual, current temperature in the bedroom. Instead, the thermostat can indicate a current temperature for the portion of the home where the thermostat is located. The ambient temperature value determined by the ambient temperature classifier can therefore be a more accurate reading of the current temperature in the bedroom. Moreover, the ambient temperature value can be more accurate than temperature readings of the thermostat because the ambient temperature value can be based on a variety of factors (e.g., barometric pressure, air bladder pressure, user/sleeper microclimate temperature) that may otherwise not be detected or used by the thermostat to determine the current temperature in the portion of the home where the thermostat is located. Using the ambient temperature value to control the HVAC unit can be advantageous to provide more accurate and preferred heating or cooling to the room where the user is currently sleeping. When control of the HVAC unit is based on temperature values of rooms other than the room where the user is sleeping, the user may wake up, become uncomfortable, or otherwise sleep poorly (e.g., the temperature detected by the HVAC thermostat can be much higher than the ambient temperature value of the bedroom. Nevertheless, the HVAC may be turned on to blast cold air into every room in the home in order to lower the home temperature from the

temperature detected by the thermostat, thereby making the user colder, too cold, or otherwise uncomfortable in the bedroom. This discomfort can disrupt the user's sleep and sleep quality).

[00215] The ambient temperature classifier can determine the ambient temperature value for the particular time based on the readings that are provided as input in 2116. Thus, the ambient temperature classifier can determine real time ambient temperature based on currently detected bladder pressure,  
5 barometric pressure, and/or microclimate temperature.

[00216] The ambient temperature classifier can be trained with machine learning processes to make such a determination. Training can be performed using training data that includes bladder pressure reading to barometric pressure reading pairs and training ambient temperature values. In other words the ambient temperature classifier can be trained to identify associations between different bladder pressure  
10 readings and barometric pressure readings. The ambient temperature classifier can then be trained to correlate such associations with different ambient temperature values.

[00217] Training can be performed by a remote computing system. Training can also be performed at the controller 1902. Sometimes, the ambient temperature classifier can be stored and accessed  
15 locally at the controller 1902. Other times, the ambient temperature classifier can be a cloud-based service that the controller 1902 communicates with (e.g., wirelessly) over one or more networks. Moreover, the ambient temperature classifier can be continuously trained based on determinations made by the ambient temperature classifier during run time. Continuous training can be beneficial to improve accuracy in determining ambient temperature values by the ambient temperature classifier.

[00218] The ambient temperature classifier can determine temperature in the ambient environment using a variety of techniques. For example, the ambient temperature classifier can perform a calculation that removes the influence of the barometric pressure on the bladder pressure to determine the ambient temperature value.

[00219] As another example, the ambient temperature classifier can determine a thermal pressure  
25 value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings. The ambient temperature classifier can then determine the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature. The model can be

based on an ideal gas law. Moreover, the contents of the air bladder can include both a gas and an open cell foam. The model can further be based on thermal expansion properties of the open cell foam.

[00220] As yet another example, the ambient temperature classifier can determine the ambient temperature value by looking up the ambient temperature in a lookup table indexed by bladder pressure and barometric pressure. The lookup table can indicate what bladder pressure and barometric pressure readings are associated with which ambient temperature values. Oftentimes, increased pressure readings can indicate a higher temperature, while decreased pressure readings can indicate a lower temperature. The lookup table can provide ranges and/or exact ambient temperature values based on different bladder pressures and barometric pressures. The lookup table can be locally stored and accessed at the controller 1902. The lookup table can also be stored in a data store that is in communication (e.g., wireless) with the ambient temperature classifier over one or more networks.

[00221] When the readings that are provided as input include the microclimate temperature readings, the ambient temperature classifier can determine temperature in the ambient environment by removing the influence of the barometric pressure and the microclimate temperature on the bladder pressure. After all, the microclimate temperature can cause pressure on the air bladder. The warmer the user's body is, the more pressure will be applied to the air bladder. Thus, the microclimate temperature can be taken into account when identifying how much pressure is applied to the air bladder, which can further correspond to the ambient temperature value.

[00222] Based on the ambient temperature value, the controller 1902 can determine a home automation event in 2120. For example, the controller 1902 can determine one or more home automation events that can be performed by the automation controller 1914 based on the ambient temperature value. The controller 1902 can determine whether the ambient temperature value is above or below a threshold temperature value or range. The threshold temperature value or range can be determined by the controller 1902 and based on historic temperature values of the environment surrounding the bed system. The threshold temperature value or range can be based on prior or historic sleep metrics associated with the user of the bed system. For example, the controller 1902 (or another computing system in communication with the bed system) can determine one or more ambient conditions, such as the threshold temperature value or range, that provides the user with optimal sleep experience and sleep quality based on analysis of prior

sleep patterns of the user. Sometimes, the threshold temperature value or range can be set by the user and provided to the controller 1902 as user input from a user computing device (e.g., a mobile application presented at the user's smartphone) that is in communication with the controller 1902.

[00223] If the ambient temperature value is above the threshold temperature value or range, then the controller 1902 can determine a home automation event of actuating a cooling system in the home (e.g., turning on the HVAC unit). In other words, the controller 1902 can determine that the room where the bed system is located is currently too warm. The temperature can be lowered in order to bring the temperature of the room to a more desirable temperature for providing the user with optimal sleep quality and comfort. The controller 1902 can also determine that the cooling system may remain turned on until a new ambient temperature value is determined at a later time and that ambient temperature value is below the threshold temperature value or range. Sometimes, the controller 1902 can determine that the cooling system may remain turned on for a predetermined amount of time.

[00224] If, on the other hand, the ambient temperature value is below the threshold temperature value or range, then the controller 1902 can determine a home automation event of actuating a heating system in the home. In other words, the controller 1902 may determine that the room where the bed system is located is too cold for the user to experience optimal sleep quality and comfort. Increasing the temperature in the room can therefore improve the user's sleep quality and comfort. The controller 1902 can also determine that the heating system may remain turned on until a new ambient temperature value is determined at a later time that is above the threshold temperature value or range. As mentioned above, the controller 1902 can also determine that the heating system may remain turned on for a predetermined amount of time.

[00225] In some implementations, the determined home automation event can simply be turning off a heating or cooling system in the home. In other words, the heating or cooling system may already be turned on in the home. Where the ambient temperature value is below the threshold temperature value or range, the controller 1902 can determine that the cooling system should be turned off. This is because a desired, cool temperature may already be reached in the room where the bed system is located. On the other hand, where the ambient temperature value is above the threshold temperature value or range, the controller

1902 can determine that the heating system should be turned off. This is because a desired, warm temperature may already be reached in the room where the bed system is located.

[00226] One or more other home automation events can be determined, including but not limited to changing lighting in the environment surrounding the bed system or changing one or more settings of the bed system. As an illustrative example, a home automation event can include raising or lowering blinds in the room where the bed system is located in order to filter how much sunlight enters and heats up the room. When the ambient temperature value exceeds the threshold temperature value or range, the controller 1902 can determine that the blinds should be lowered to reduce how much more sunlight enters the room and heats up the room (e.g., this can occur during the summer, midday, etc.). On the other hand, when the ambient temperature value is less than the threshold temperature value or range, such as in the morning after the temperature has lowered during the night (e.g., or during the winter), the controller 1902 can determine that the blinds should be raised to let in more sunlight and subsequently to heat up the room with the sunlight.

[00227] As another illustrative example, heating or cooling elements of the bed system can be actuated or deactivated. When the ambient temperature value exceeds the threshold temperature value or range, a cooling element can be actuated in the bed system in order to reduce a microclimate temperature of the user on the bed system. The surrounding environment can be warm, but the bed system temperature can be adjusted to make the user more comfortable by cooling the top surface of the bed system. This can be beneficial in scenarios where a heating or cooling unit is not in the room where the bed system is located or a heating or cooling unit of the home does not provide direct heating or cooling to the room where the bed system is located. This can also be beneficial in scenarios where a heating or cooling unit in the home is activated but additional heating or cooling is needed (e.g., during a heat wave or a winter storm, when there are extreme temperatures it can be preferred to implement multiple home automation events). Similarly, when the ambient temperature value is less than the threshold temperature value or range, a heating element can be actuated in the bed system in order to increase a microclimate temperature of the user on the bed system. As a result, the user can be more directly warmed when heat is provided to the top surface of the bed system. One or more other home automation events or bed system adjustments are possible.

[00228] Sometimes, the controller 1902 can identify discontinuities, greater than a threshold value, in a record of ambient pressure values over time. The identified discontinuities can indicate bed entry and exit events. For example, when a user is sleeping on the bed system, additional pressure from the user's body can be applied to the air bladder of the bed system. The user's microclimate temperature can also  
5 apply more pressure to the air bladder. Consequently, the ambient temperature value can be a higher temperature value based on the increased pressure that is detected on the air bladder. When this ambient temperature value remains relatively consistent for some predetermined amount of time (e.g., 7 or more hours), the controller 1902 can determine that the user has entered the bed system and is sleeping on the bed system for that period of time. The controller 1902 can also determine whether over time, the ambient  
10 temperature remains relatively the same and consistent for the predetermined amount of time (e.g., every day for 8 hours each day, the ambient temperature value is approximately the same). If the ambient temperature remains relatively the same and consistent, the controller 1902 can determine that same or similar home automation events can be made each night that the user has entered the bed system and is sleeping on the bed system.

[00229] Likewise, if the ambient temperature value suddenly drops and remains at that lower value for some predetermined amount of time, the controller 1902 can determine that the user has exited the bed system. After all, when the user gets up from the bed, pressure from the user's body and microclimate temperature of the user are removed from the bed system (e.g., and more specifically, the air bladder). The ambient temperature value would be lower. If the controller 1902 determines that the user  
15 exited the bed system, the controller 1902 may not determine any home automation events until a triggering condition occurs. The triggering condition can include detection of different readings by the sensors 2002, 2004, and 2006, determination of a new ambient temperature value, and/or passing of a predetermined amount of time.

[00230] Next, the automation controller 1914 initiates the home automation event in 2122. As  
25 mentioned above, the automation controller 1914 and the controller 1902 can be separate components in data communication (e.g., wired, wireless) via one or more networks. Sometimes, the automation controller 1914 can be the same as the controller 1902 or otherwise part of a same component, computing system, mobile computing device, and/or server, as described above in reference to FIGs. 19-20. Thus, sometimes

the controller 1902 can initiate the home automation event in 2122 instead of the automation controller 1914. Sometimes, the controller 1902 can initiate some home automation events (e.g., activating/deactivating heating or cooling elements of the bed system) and the automation controller 1914 can initiate other home automation events (e.g., activating/deactivating the HVAC unit of the home).

**WHAT IS CLAIMED IS:**

1. A system for measuring ambient temperature, the system comprising:
  - a mattress for supporting a sleeper, the mattress comprising at least one air bladder;
  - a bladder pressure sensor fluidically coupled to the air bladder, the bladder pressure sensor configured to:
    - sense bladder pressure inside the air bladder for a particular time;
    - transmit bladder pressure readings for the particular time;
  - a barometric sensor in an ambient environment outside the mattress, the barometric sensor configured to:
    - sense barometric pressure in the ambient environment for the particular time;
    - transmit barometric pressure readings for the particular time;
  - a computing device comprising at least one processor and memory, the computing device configured to:
    - receive the bladder pressure readings;
    - receive the barometric pressure readings;
    - provide, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings; and
    - receive, as output from the ambient temperature classifier, an ambient temperature value for the particular time.
2. The system of claim 1, wherein the ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure.
3. The system of claim 1, wherein the ambient temperature classifier is configured to:
  - determine a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and
  - determine the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature.
4. The system of claim 3, wherein the model is based on an ideal gas law.
5. The system of claim 4, wherein the contents of the air bladder include both a gas and an open cell foam, and wherein the model is further based on thermal expansion properties of the open cell foam.

6. The system of any of the claims 1-5, wherein the ambient temperature classifier is configured to find the ambient temperature by looking up the ambient temperature in a lookup table indexed by bladder pressure and barometric pressure.
7. The system of any of the claims 1-5, wherein the ambient temperature classifier was trained with machine learning processes using training data comprising i) bladder pressure reading:barometric pressure reading pairs and ii) training ambient temperature values.
8. The system of any of the claims 1-5, wherein:
  - the system further comprises a temperature sensor configured to:
    - sense microclimate temperature in a microclimate around the sleeper;
    - transmit the microclimate temperature readings for the particular time;
  - the computing device is further configured to:
    - receive the microclimate temperature readings; and
    - provide, as further input to the ambient temperature classifier, the microclimate temperature readings.
9. The system of claim 8, wherein the ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure and of the microclimate temperature on the bladder pressure.
10. The system of any of the claims 1-5, where the computing device is further configured to identify discontinuities, greater than a threshold value, in a record of ambient pressure values over time as bed entry/exit events.
11. The system of any of the claims 1-5, where the computing device is further configured to initiate a home automation event based on the received ambient temperature value for the particular time.
12. A computer-readable medium tangibly storing instructions that, when executed by one or more processors, cause the one or more processors to perform operations comprising:
  - receive bladder pressure readings of bladder pressure inside an air bladder of a mattress for a particular time;
  - receive barometric pressure readings of barometric pressure in an ambient environment outside the mattress for the particular time;
  - provide, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings; and

receive, as output from the ambient temperature classifier, an ambient temperature value for the particular time.

13. The computer-readable medium of claim 12, wherein the ambient temperature classifier is configured to determine temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure.
14. The computer-readable medium of claim 12, wherein the ambient temperature classifier is configured to:
  - determine a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and
  - determine the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature.
15. The computer-readable medium of claim 14, wherein the model is based on an ideal gas law.
16. The computer-readable medium of claim 15, wherein the contents of the air bladder include both a gas and an open cell foam, and wherein the model is further based on thermal expansion properties of the open cell foam.
17. A method for measuring ambient temperature, the method comprising:
  - receiving bladder pressure readings of bladder pressure inside an air bladder of a mattress for a particular time;
  - receiving barometric pressure readings of barometric pressure in an ambient environment outside the mattress for the particular time;
  - providing, as input to an ambient temperature classifier, the bladder pressure and the barometric pressure readings; and
  - receiving, as output from the ambient temperature classifier, an ambient temperature value for the particular time.
18. The method of claim 17, further comprising determining, by the ambient temperature classifier, temperature in the ambient environment by removing influence of the barometric pressure on the bladder pressure.
19. The method of claim 17, further comprising:
  - determining, by the ambient temperature classifier, a thermal pressure value for the air bladder by reducing the bladder pressure readings based on the barometric pressure readings; and

determining, by the ambient temperature classifier, the ambient temperature value in a model of contents of the air bladder that relates thermal pressure to the ambient temperature.

20. The method of claim 19, wherein the model is based on an ideal gas law.

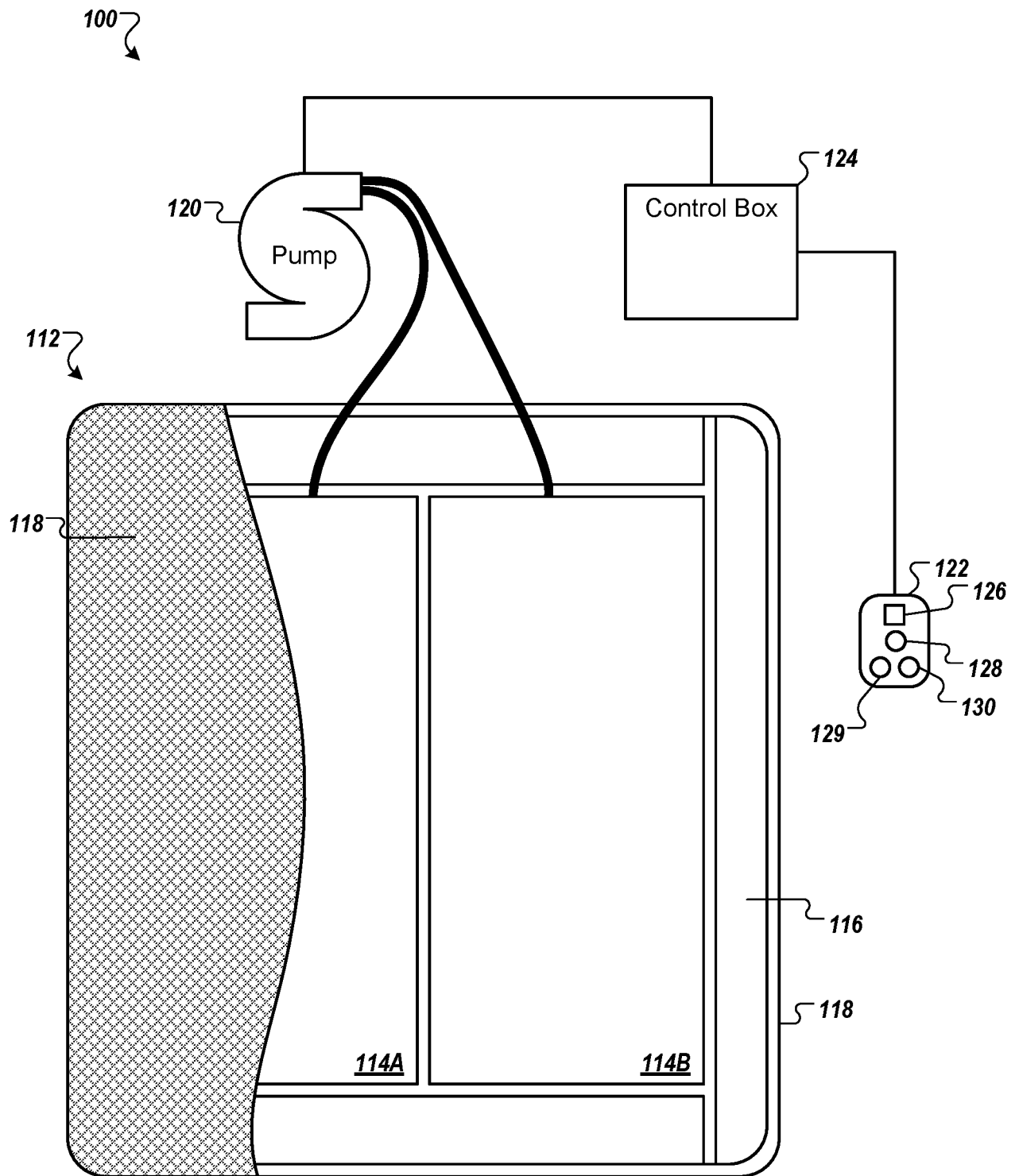


FIG. 1

100 ↷

2/22

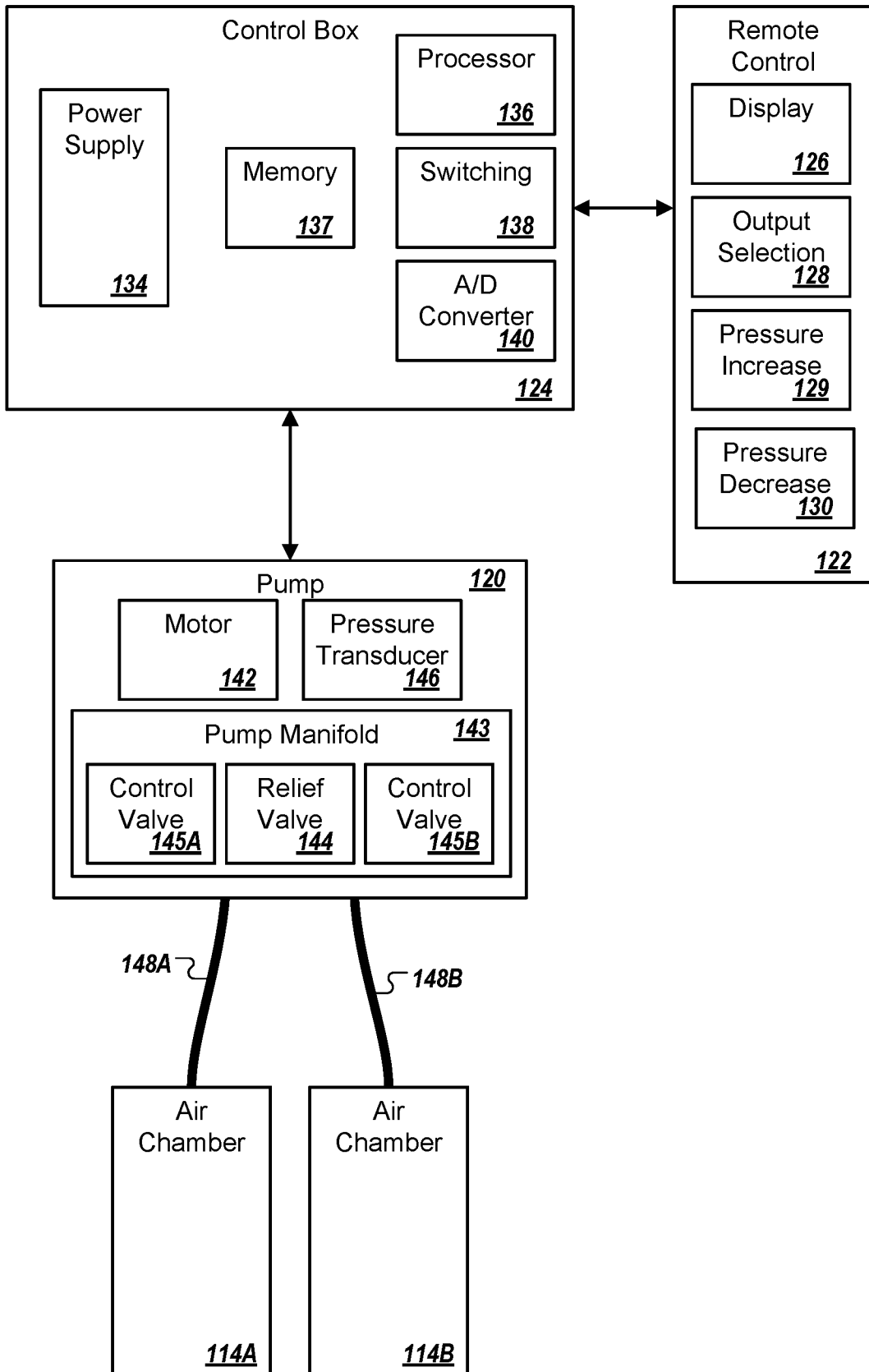


FIG. 2

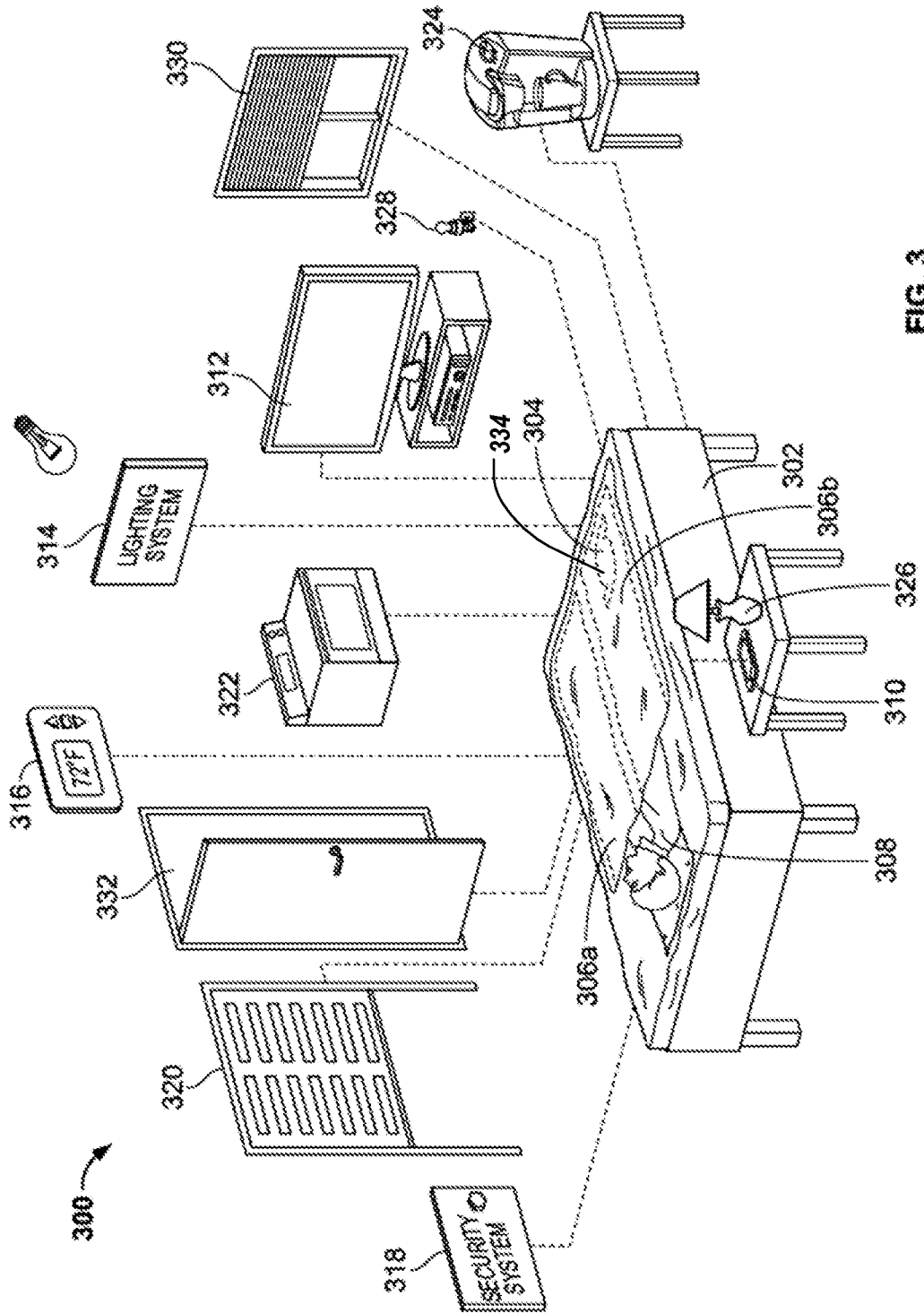


FIG. 3

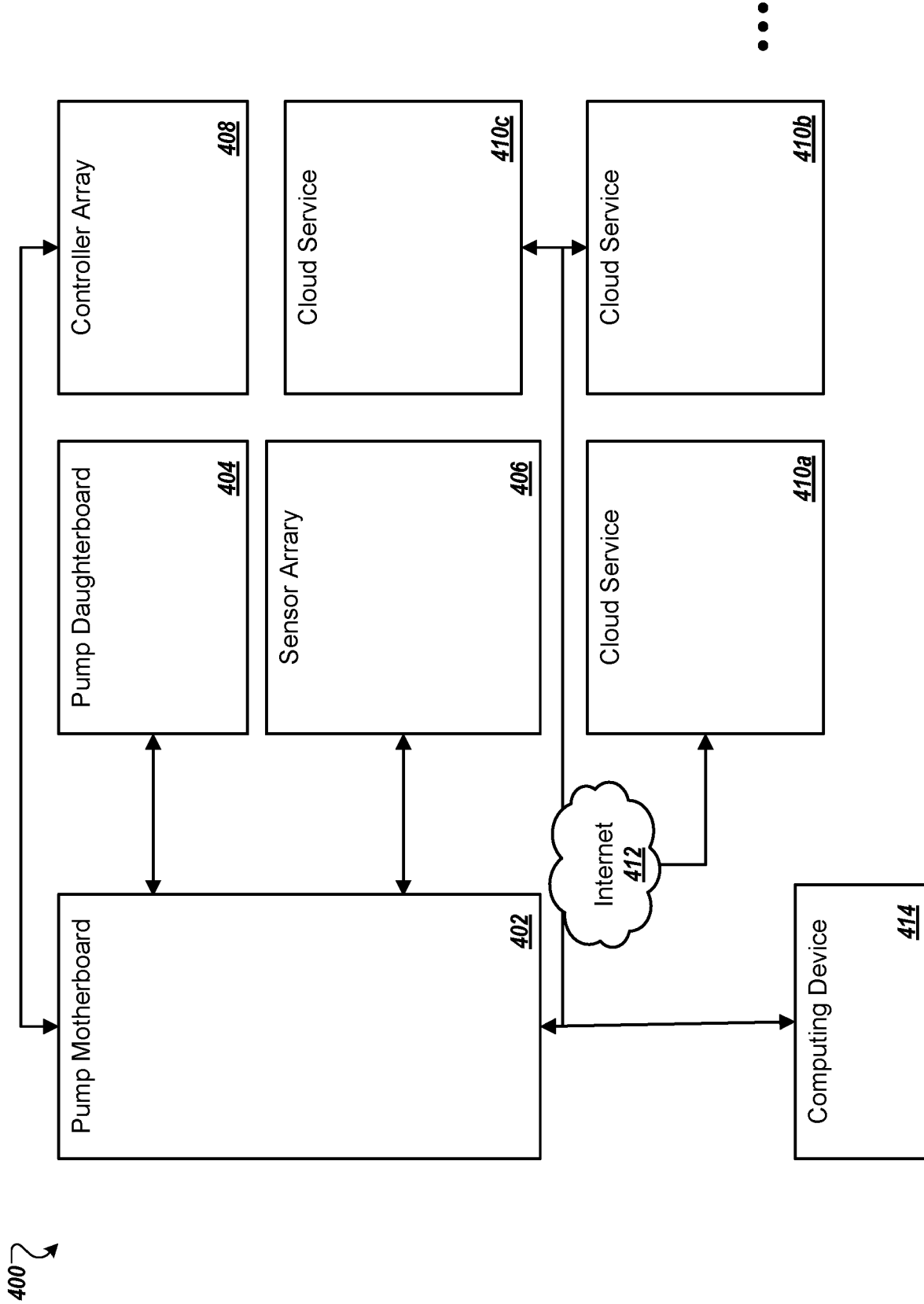


FIG. 4A

5/22

400 ↷

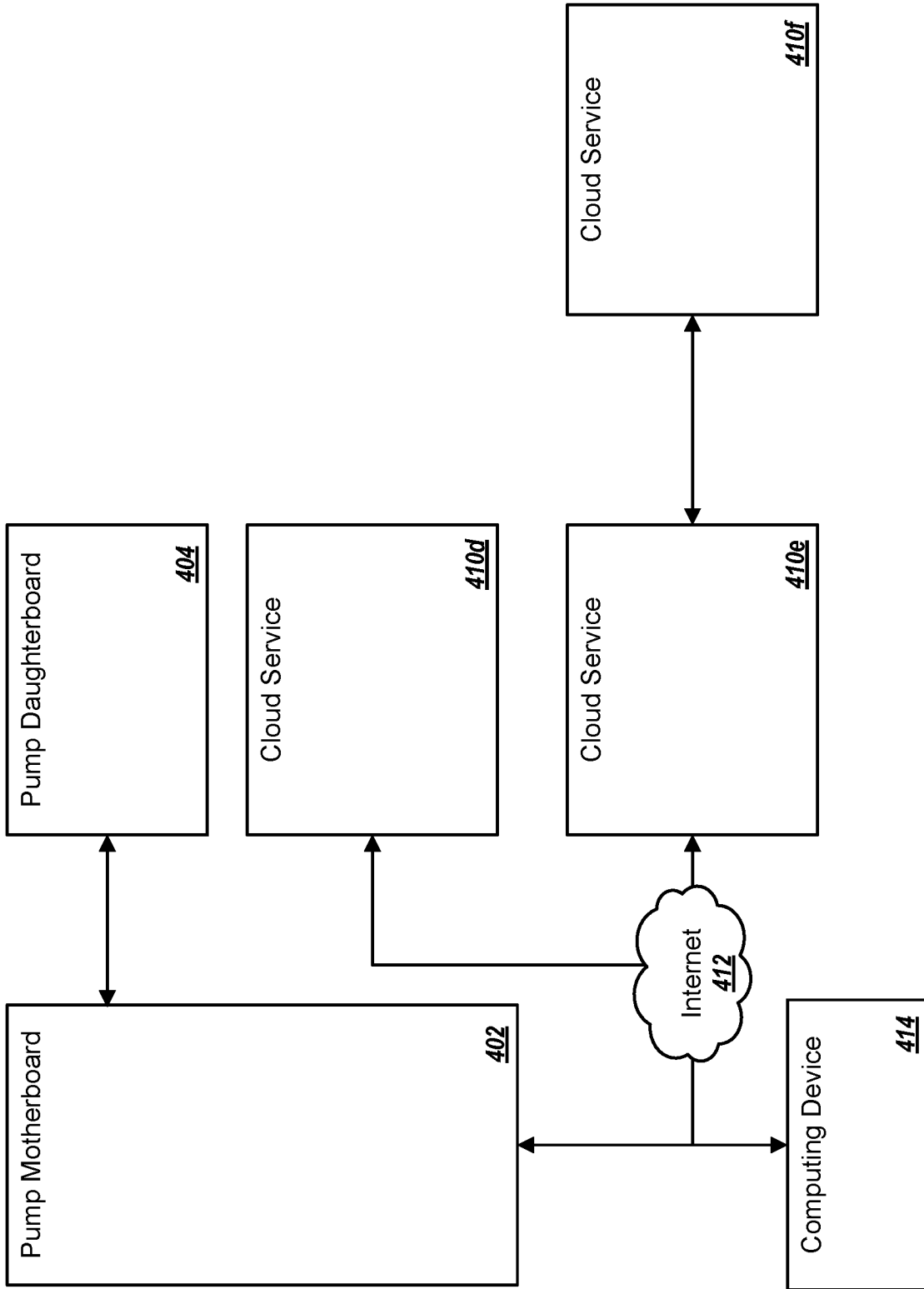


FIG. 4B

6/22

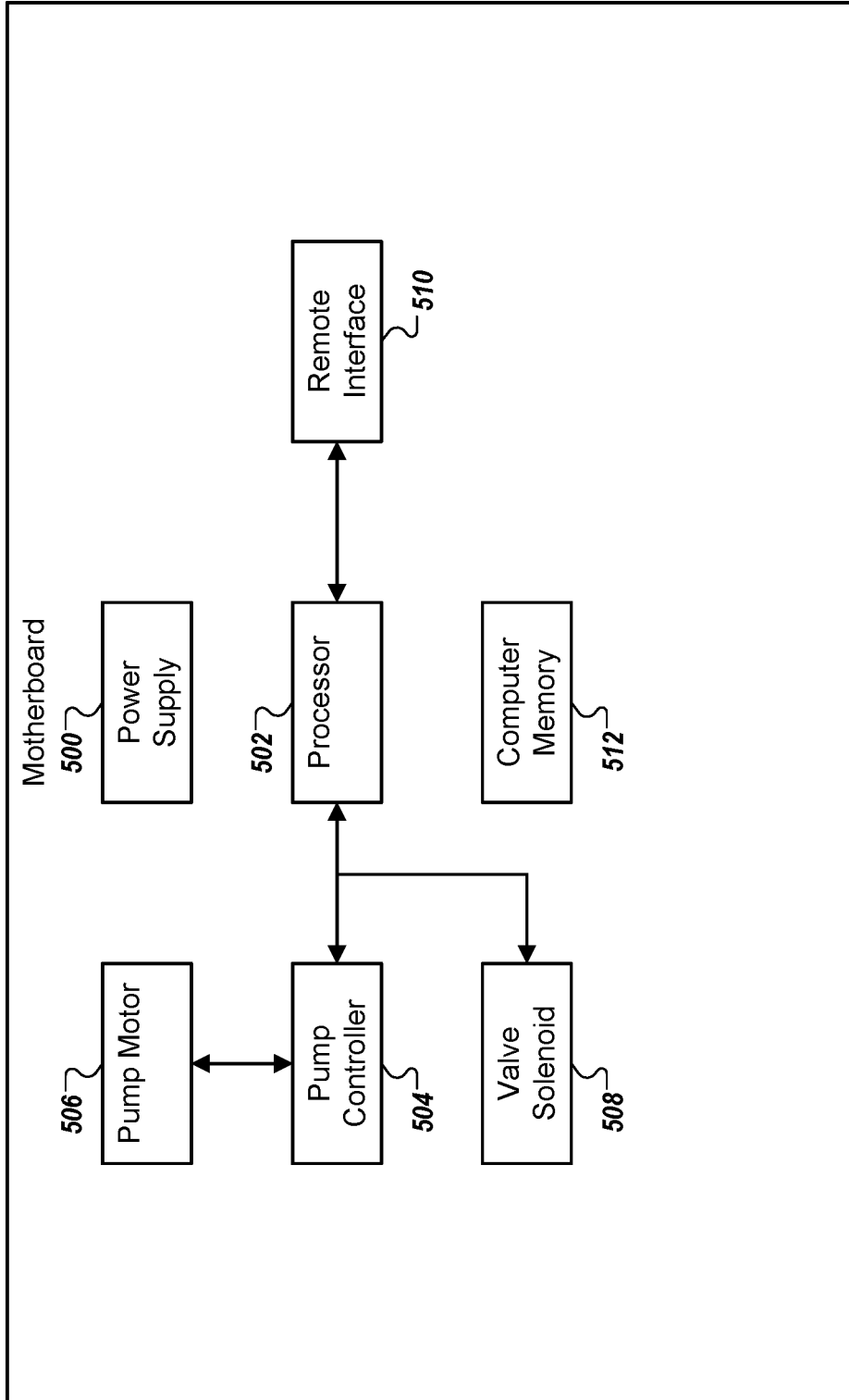


FIG. 5

402 ↗

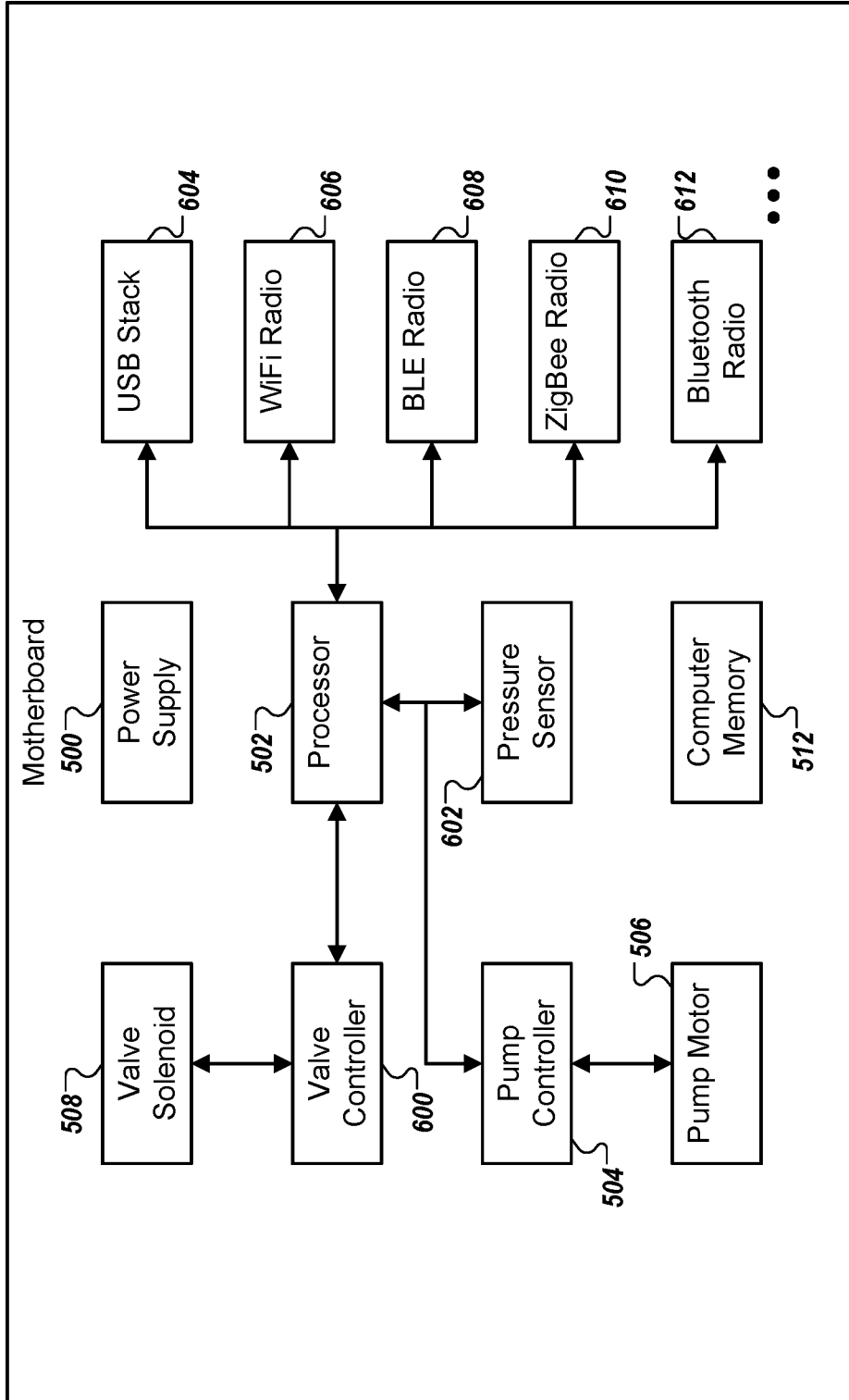


FIG. 6

404 ↷

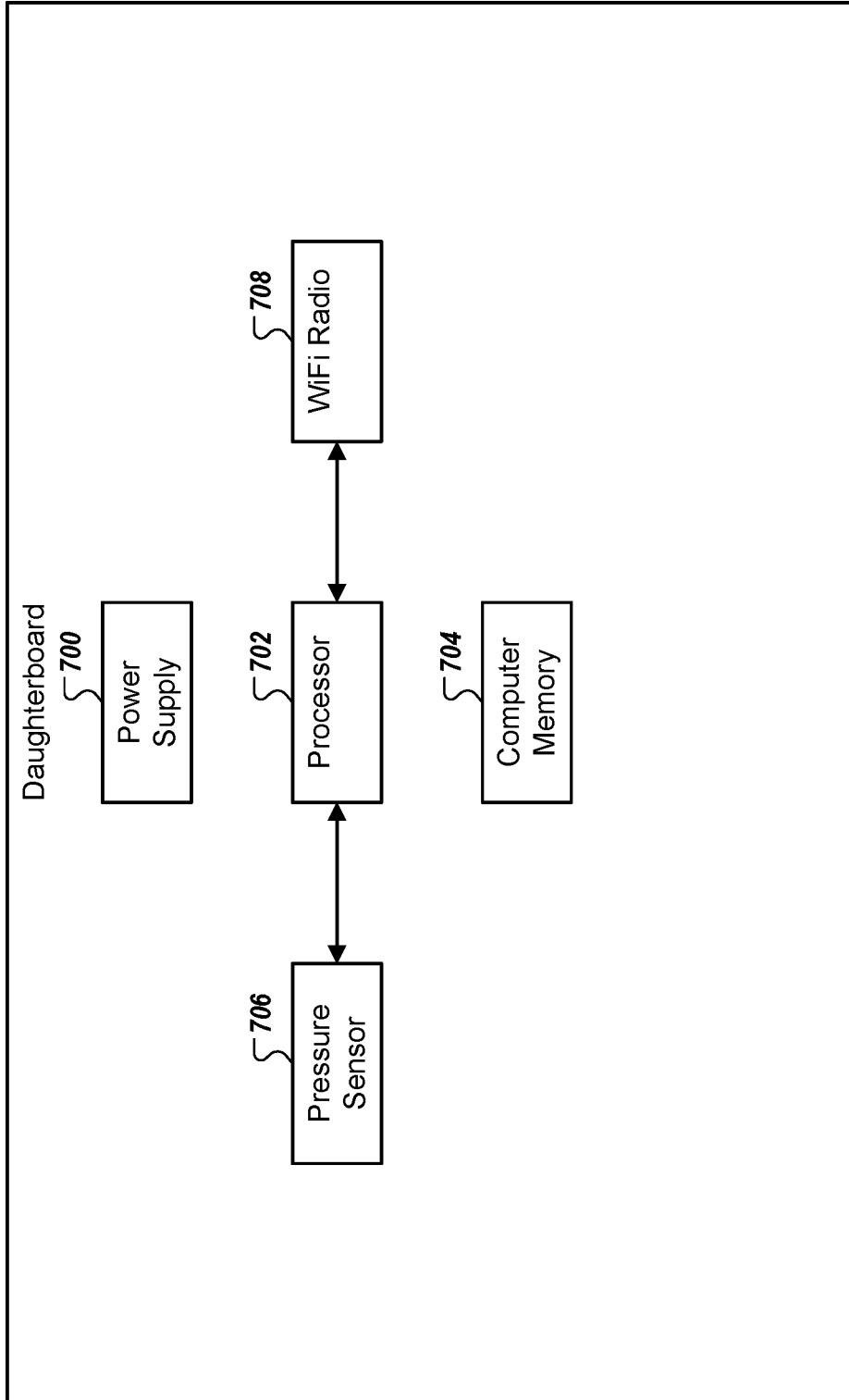


FIG. 7

9/22

800 ↗

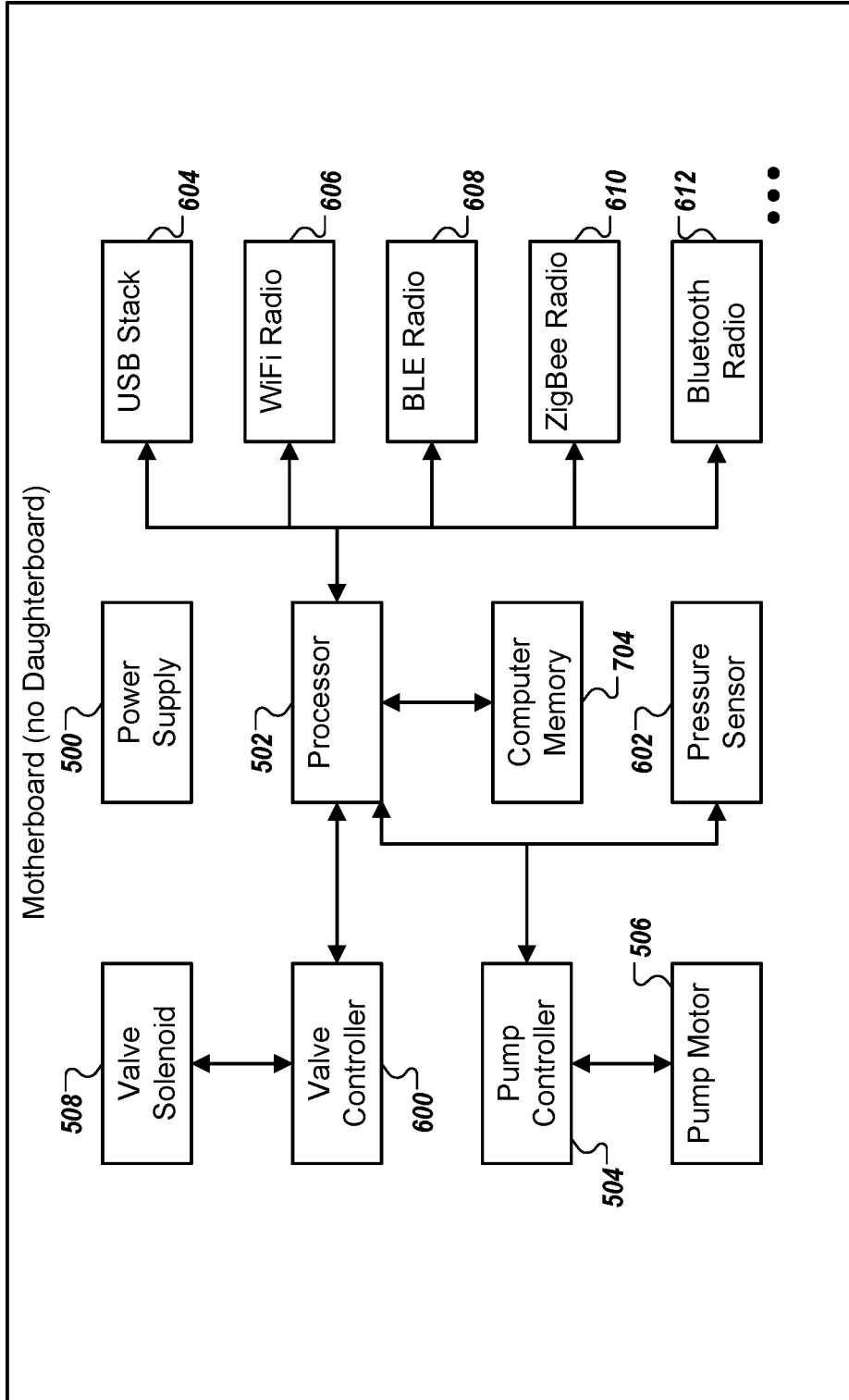


FIG. 8

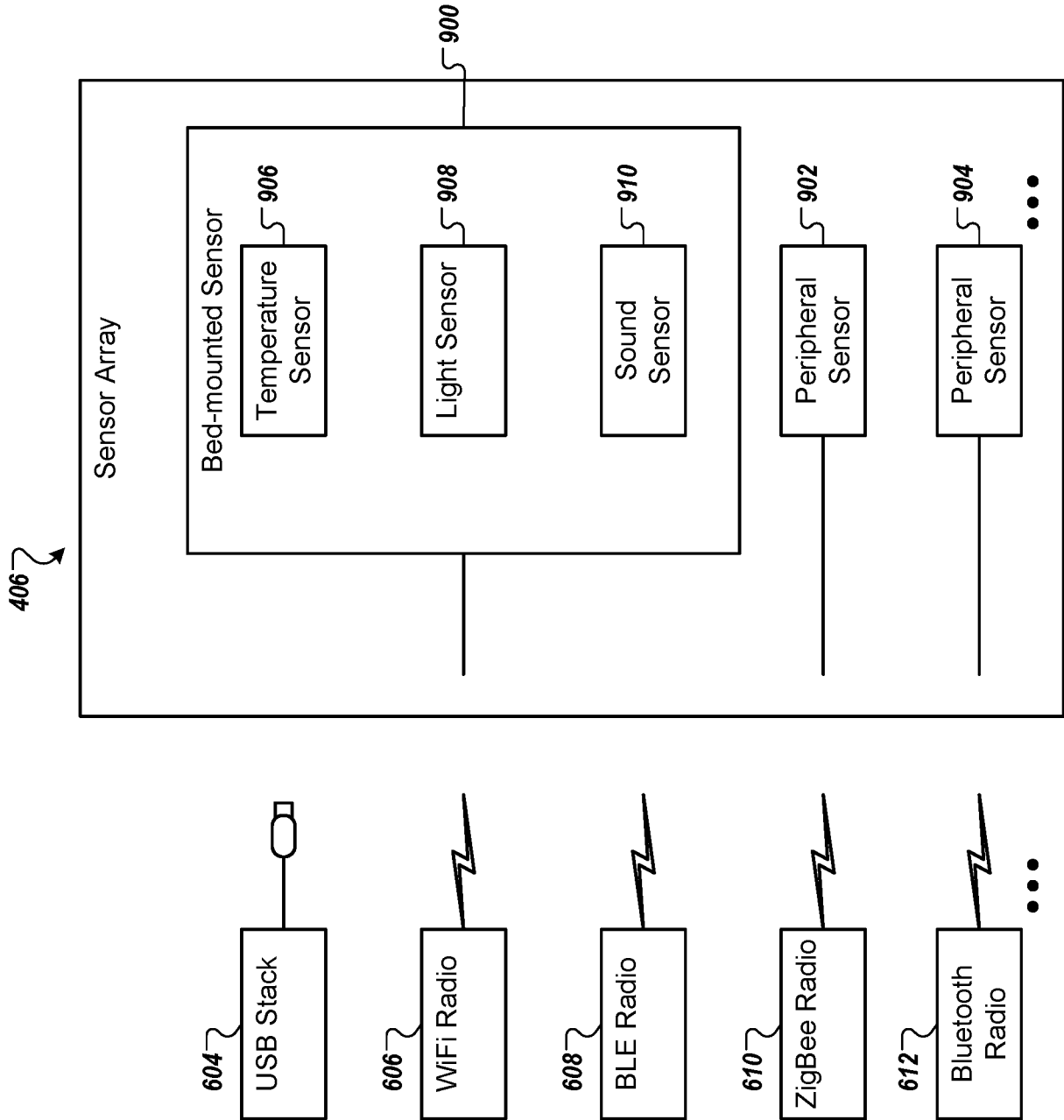


FIG. 9

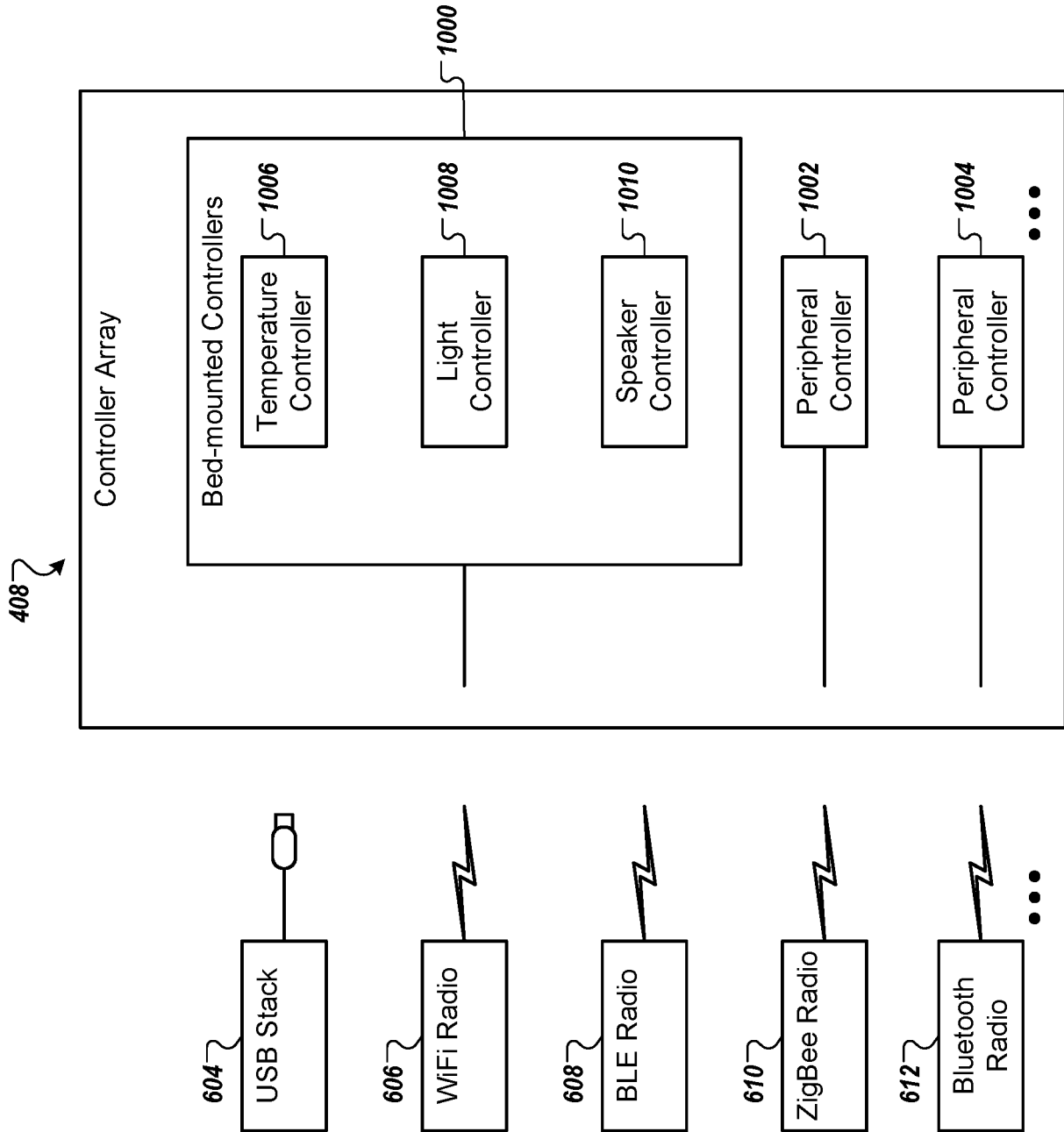


FIG. 10

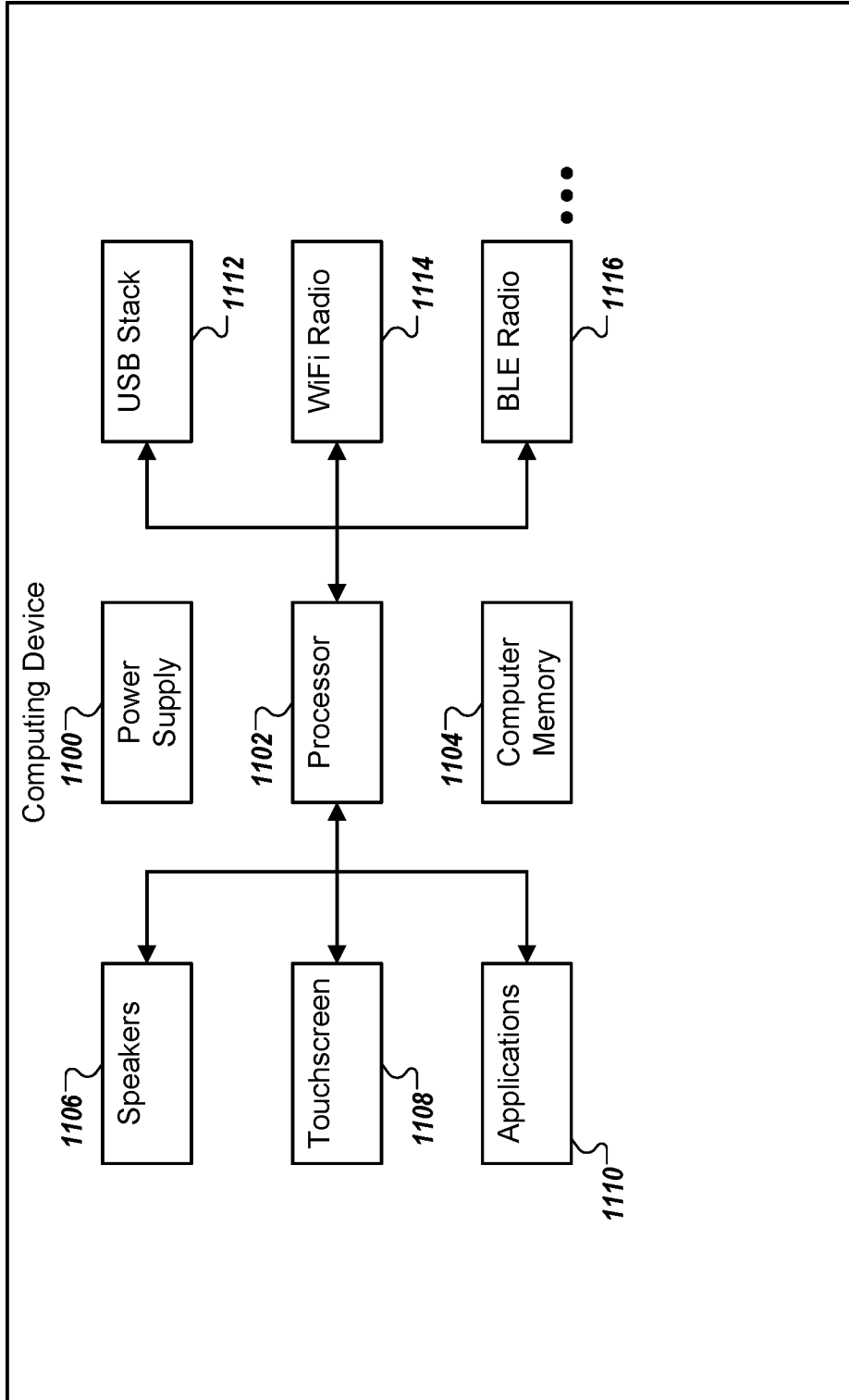


FIG. 11

414 ↗

410a ↷

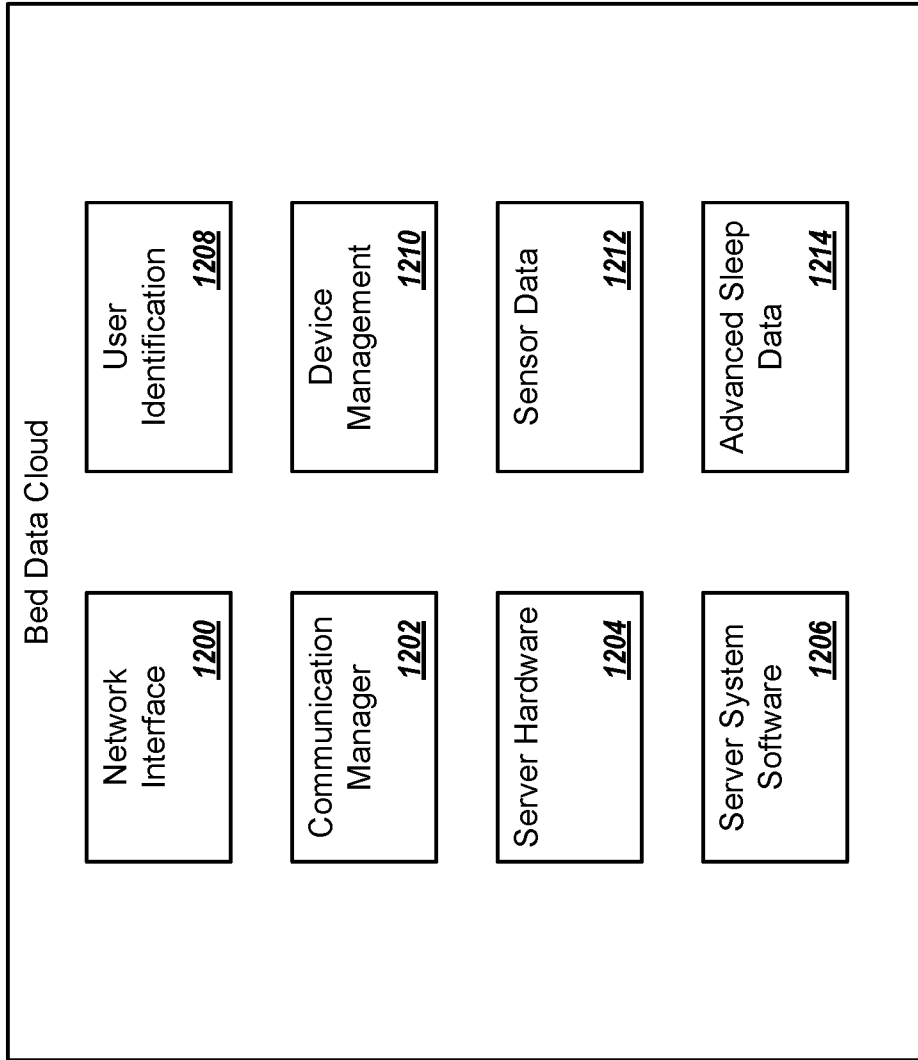


FIG. 12

410b ↷

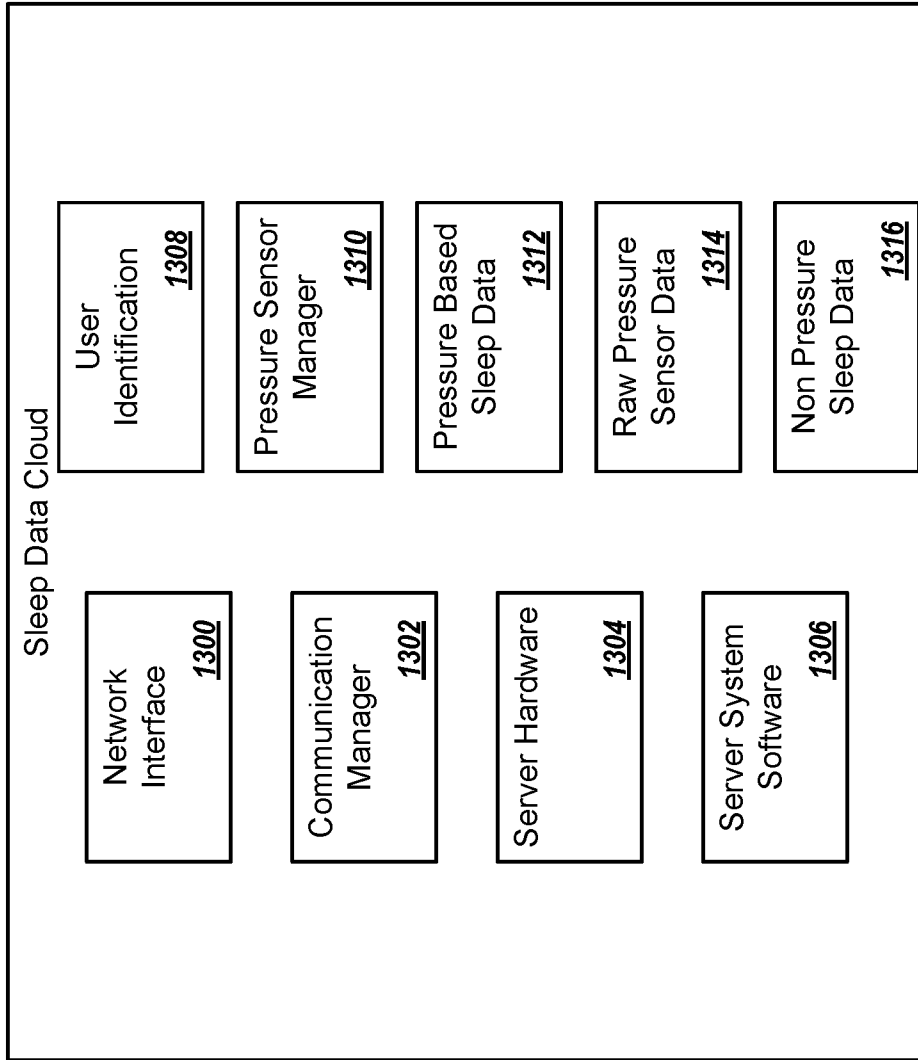


FIG. 13

410c ↷

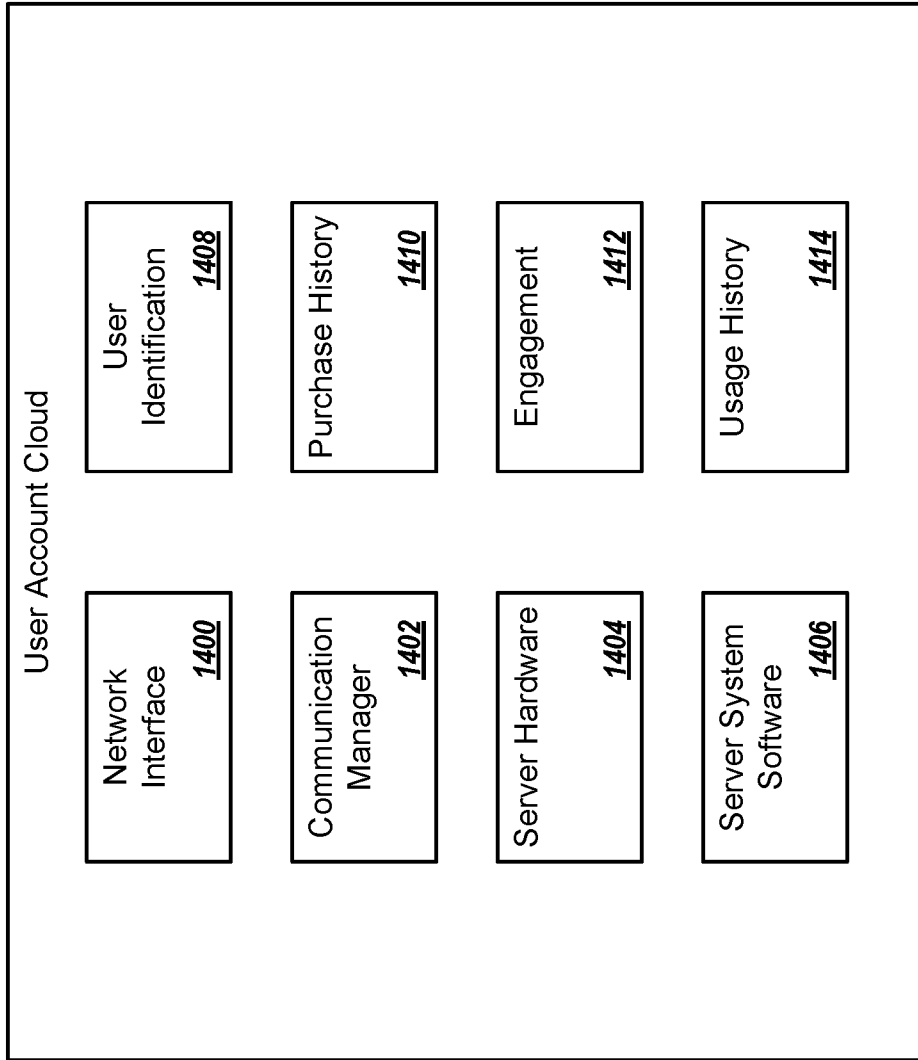


FIG. 14

1500 ↷

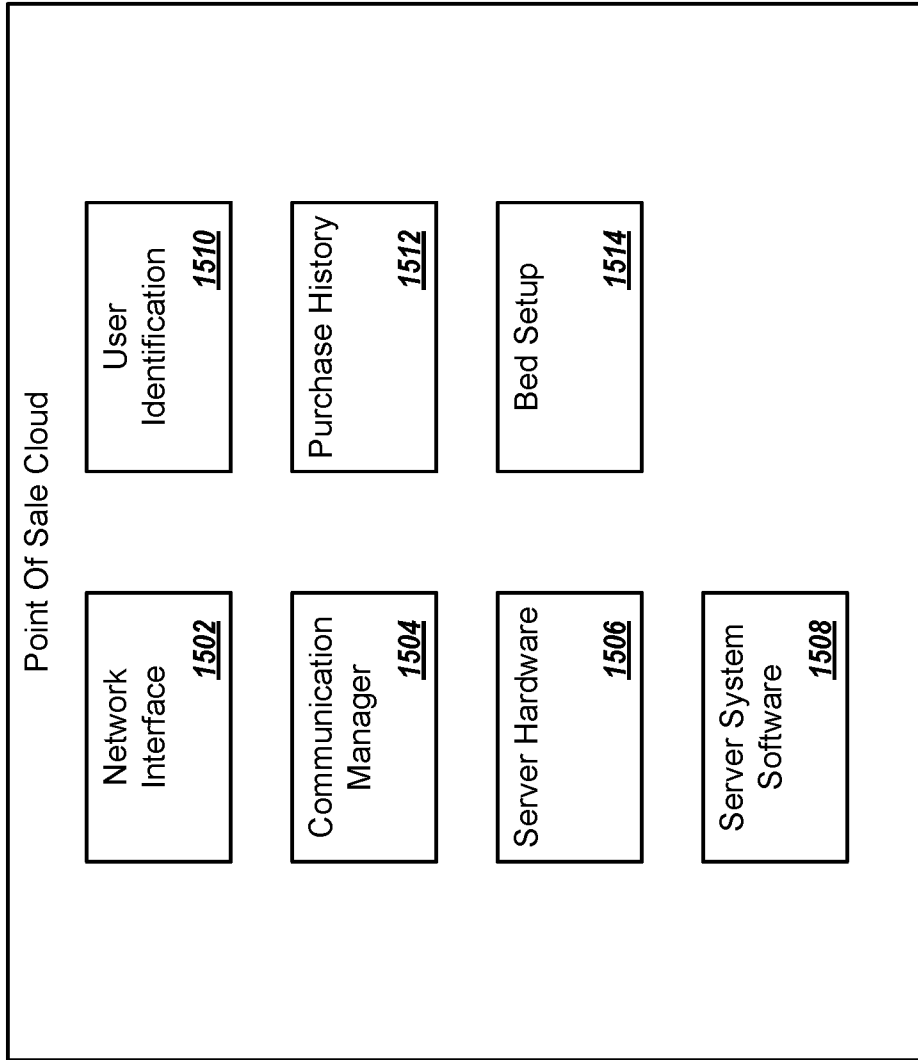


FIG. 15

1600 ↗

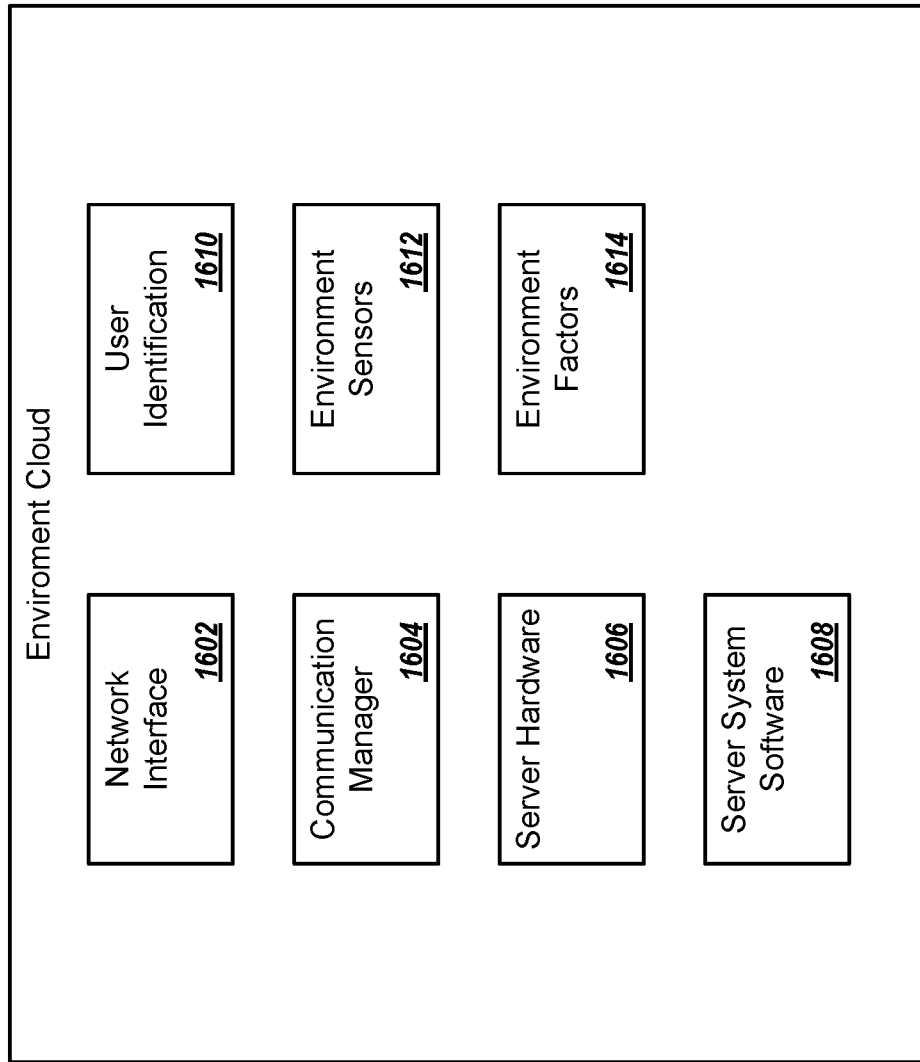


FIG. 16

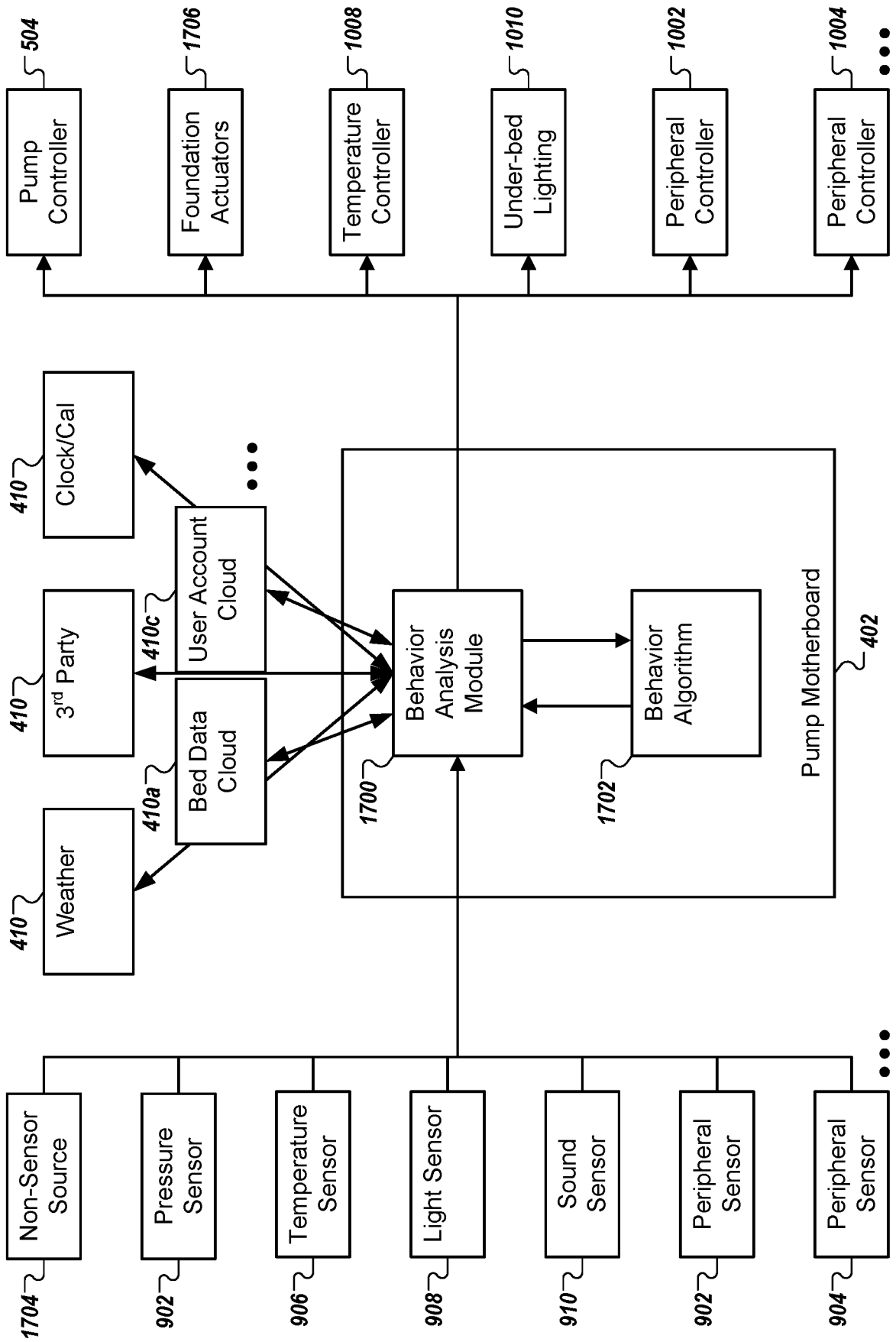


FIG. 17

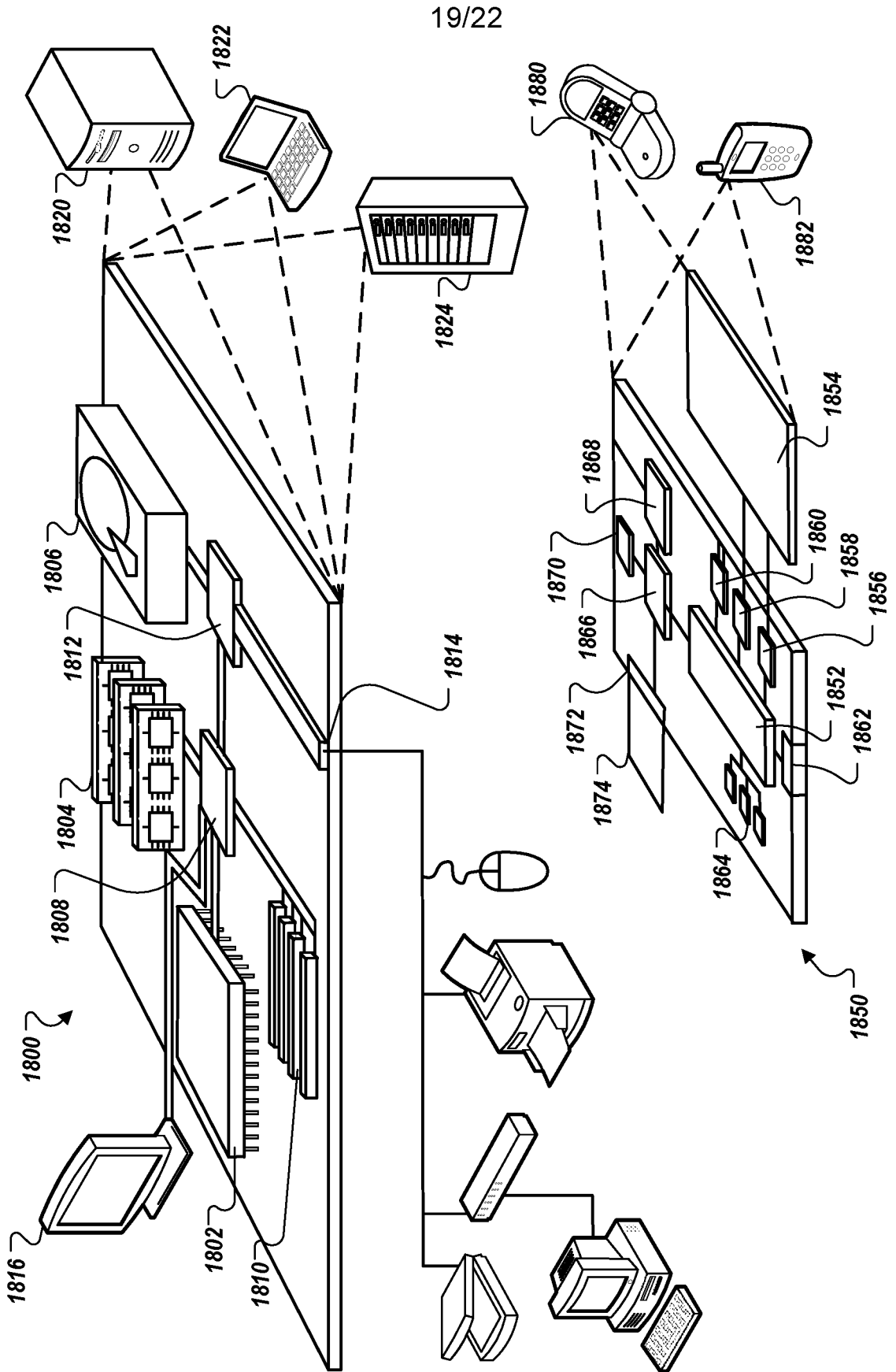


FIG. 18

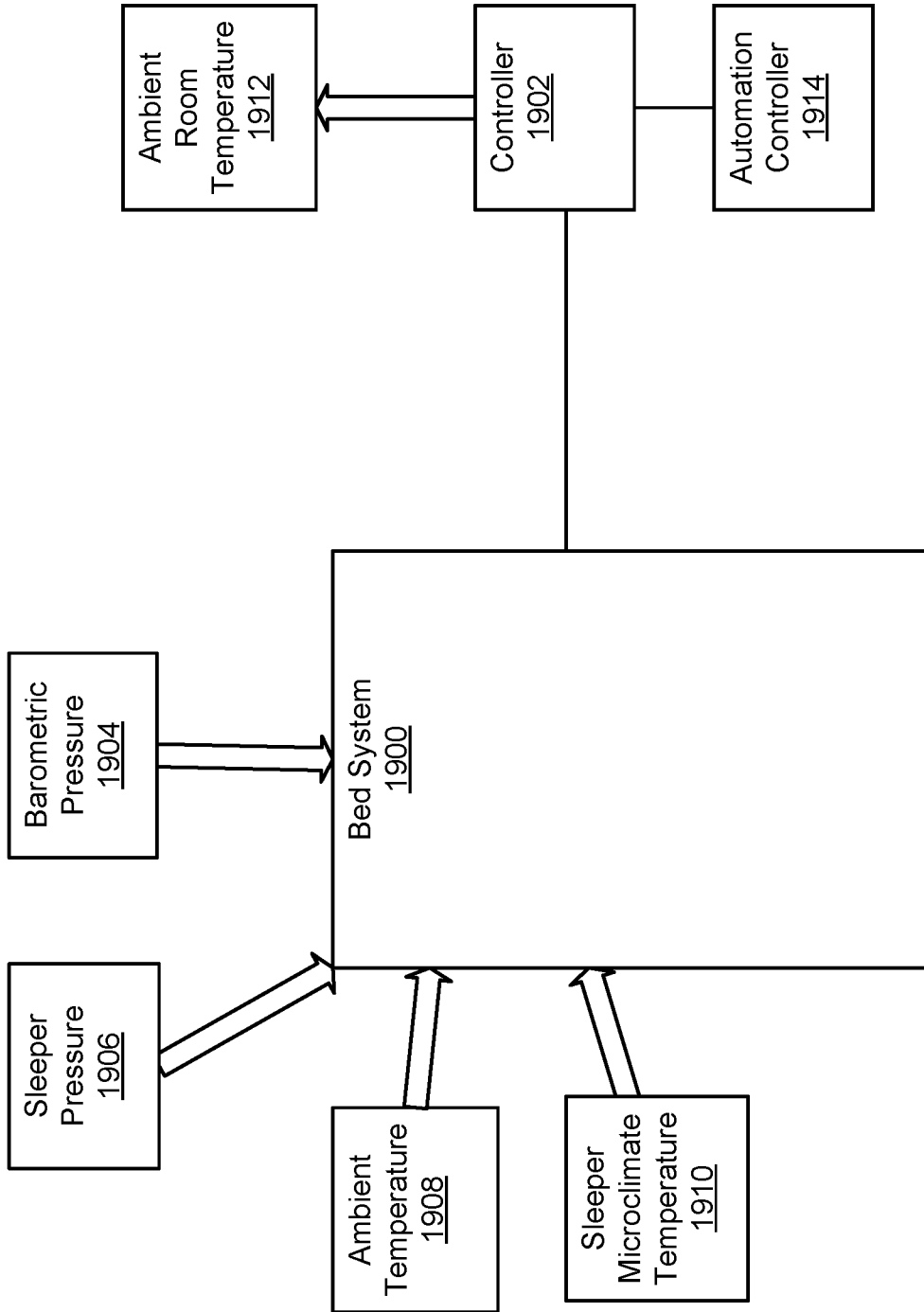


FIG. 19

1900 ↷

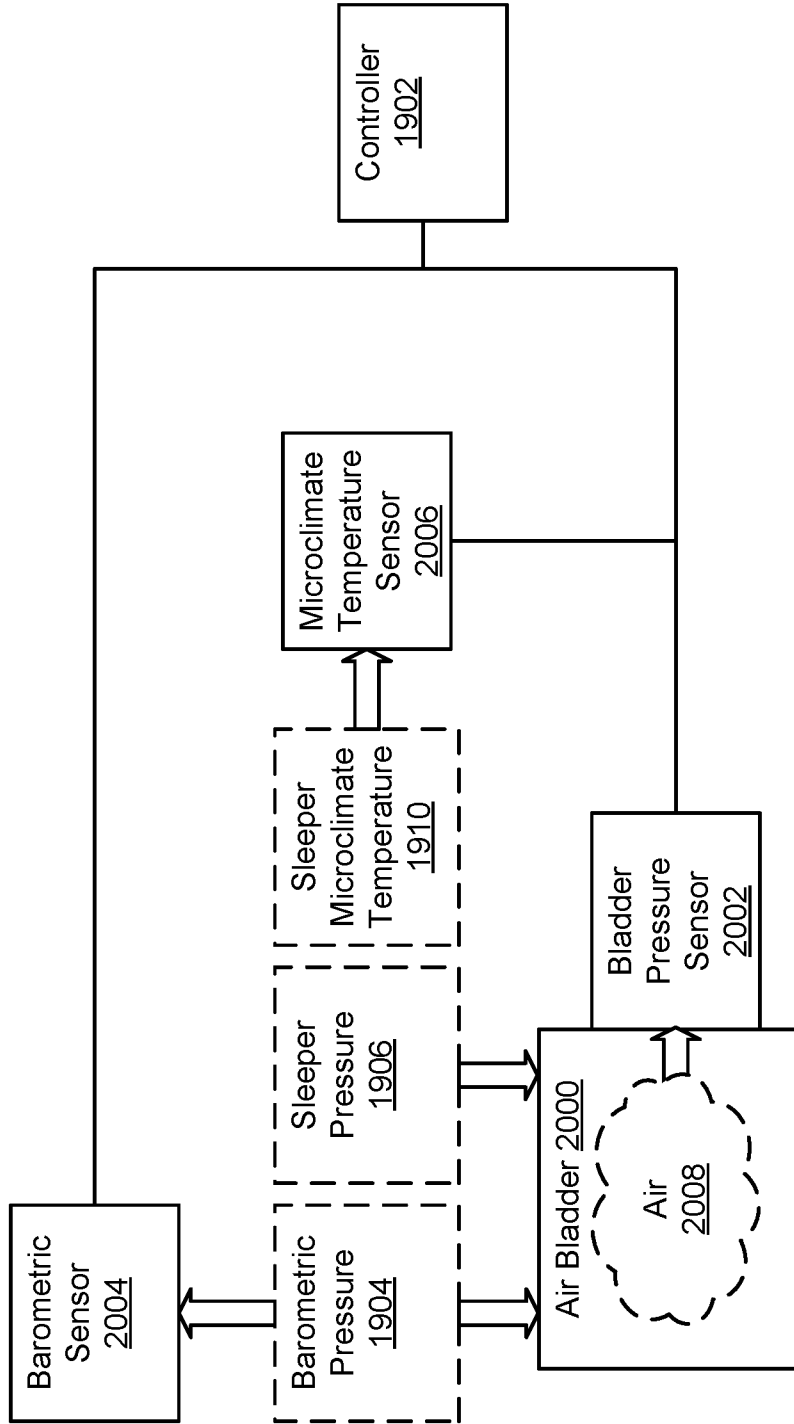


FIG. 20

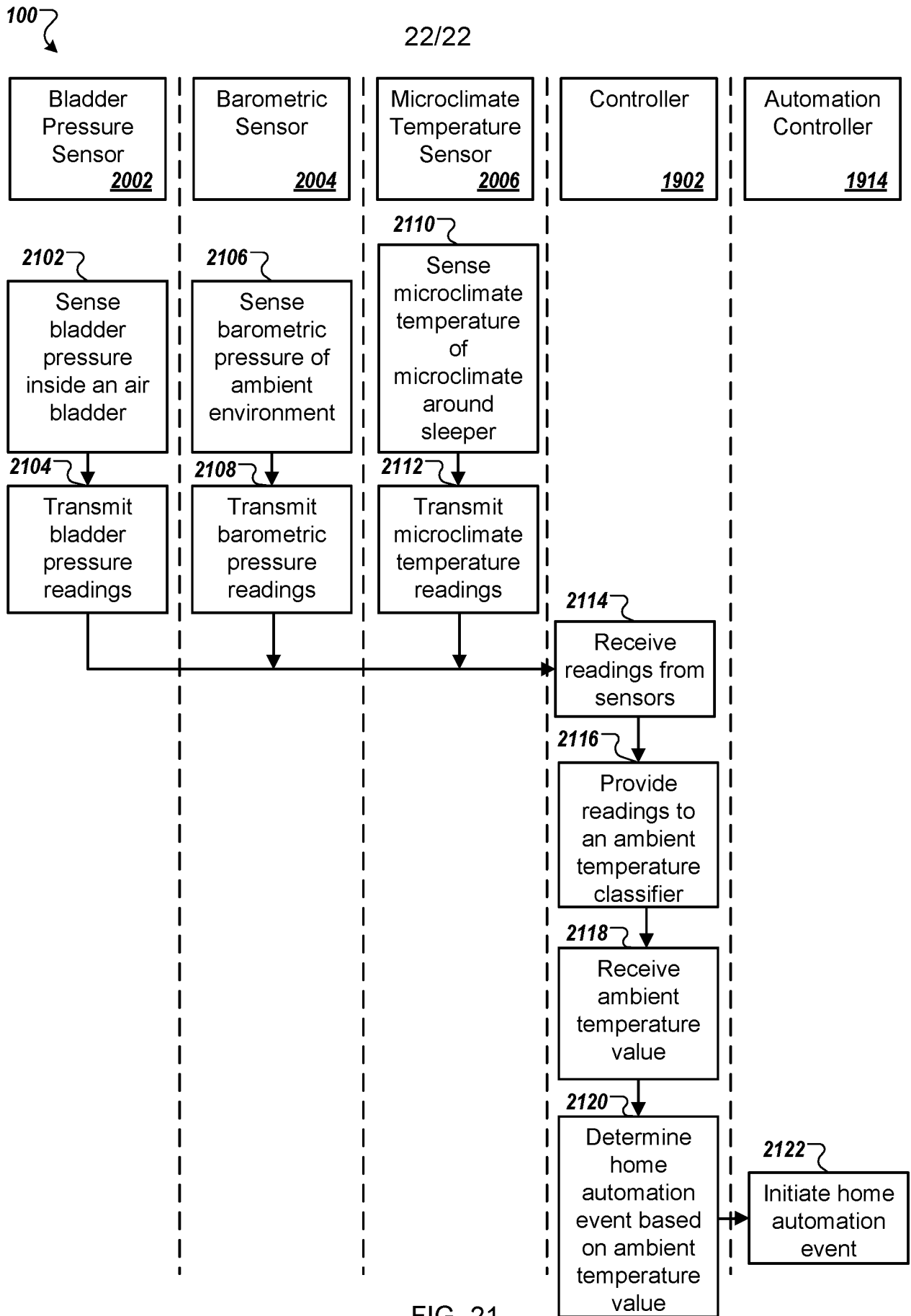


FIG. 21

# INTERNATIONAL SEARCH REPORT

International application No  
**PCT/US2022/049550**

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> <b>INV. A47C27/08 A47C27/10 A47C31/00 A47C21/00 A47C21/04</b> <b>ADD.</b>		
According to International Patent Classification (IPC) or to both national classification and IPC		
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) <b>A47C A61G</b>		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)  <b>EPO-Internal</b>		
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<b>X</b>	<b>US 2014/007656 A1 (MAHONEY PAUL JAMES [US]) 9 January 2014 (2014-01-09) paragraphs [0003], [0005], [0006], [0031] - [0039]; figures 1-6</b> -----	<b>1, 7, 8, 10-12, 17 2, 13, 18</b>
<b>A</b>	<b>US 2021/268226 A1 (YOUNGBLOOD TODD [US] ET AL) 2 September 2021 (2021-09-02) paragraph [0129]; figure 32</b> -----	<b>1-20</b>
<b>A</b>	<b>US 2015/265065 A1 (CREEKMUIR WILLIAM C [US] ET AL) 24 September 2015 (2015-09-24) paragraphs [0003], [0022]; figure 2</b> -----	<b>1-20</b>
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <span style="margin-left: 200px;"><input checked="" type="checkbox"/> See patent family annex.</span>		
* 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	Date of mailing of the international search report	
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Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer  <b>Pössinger, Tobias</b>	

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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