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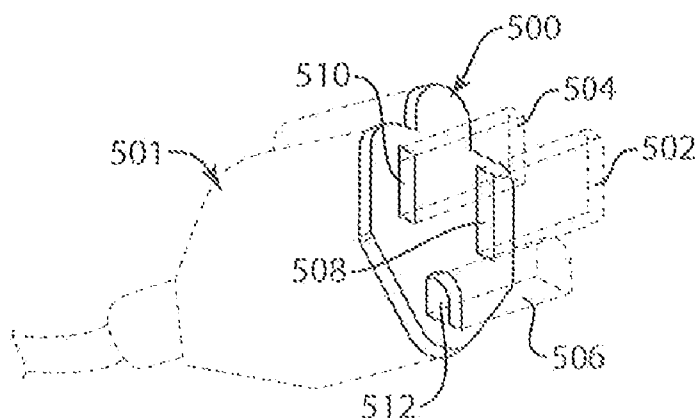


Fig. 5

(57) Abstract: In some implementations, a gasket, set forth by way of example and not limitation, includes a housing having a plurality of openings operative to receive a plurality of prongs of a power connector for an appliance. At least one sensor is operative to sense at least one characteristic of an environment. A transmitter is operative to transmit one or more signals derived from the at least one sensed characteristic, where the transmitted signals are capable of being received by a receiving device. A power circuit is operative to provide power from the electric current to the at least one sensor and the transmitter.

SENSORS FOR ELECTRICAL CONNECTORS

Field

5 This invention relates generally to electronic sensors and more particularly to wireless electronic sensing systems.

Background

 Sensing devices are used in many different applications for sensing a wide variety of different parameters or characteristics. Sensed characteristics can be used
10 to monitor the operation of mechanical, electrical, chemical, and other phenomenon. For example, sensing devices can be capable of sensing such characteristics as temperature, pressure, electric and magnetic fields, gas and vapor concentration, odor, power, audio, and video. Some sensing devices are capable of transmitting signals indicative of sensed characteristics to other devices for processing and monitoring.

15 In some applications, multiple sensing devices can be used in a sensor network. For example, some sensor networks include sensors capable of simultaneously detecting various characteristics at localized points over a wide area. When taken in aggregate, the information provided by these various sensing devices can be processed and reduced to an actionable result based on the multiple sensed locations. In some
20 implementations, each sensor device within the network can include components to read data from a transduction detector, perform some local processing, and/or send data to a centralized server. At the server, data from various sensor types and sensor locations can be used to produce an actionable result.

 Existing sensing devices tend to be large, intrusive and cumbersome. For
25 example, U.S. Patent 8,192,929 discloses a “smart wall socket” that has outlets into which appliances can be plugged, and the outlet is in turn plugged into a standard wall socket. But this device is too large and too expensive to place in an area where space

comes at a premium, nor is suitable for placement in large numbers. In another example, U.S. Patent Publication 2008/0215609 discloses sensors for collecting data and interpreting aggregate data from a network of various sensor types. However, such sensors are also of a relatively large size and often not practical to place in large numbers. In living quarters or office space, for example, numerous such large sensors would be conspicuous and impractical. In other environments, space utility is required to be optimized, as for example in a data center.

In U.S. Patent 5,589,764, a power meter is described that can be plugged into an electrical wall socket, which provides its own socket into which an electrical appliance is inserted. A measured current drawn by the appliance that is plugged into the unit is converted to energy metrics and are displayed on a display screen on the power meter. Another implementation is disclosed in U.S. Patent 8,041,369, where the measured data is transmitted wirelessly to a centralized server. These approaches make measurements by passing the current through the meter in series with the appliance. It is for this reason that these types of power meters are of a form that plugs into an outlet socket, and provide another separate outlet socket into which the appliance is plugged. However, this approach results in a power meter that is very bulky and is impractical to associate with many appliances, thereby resulting in incomplete information in environments having several appliances. Further, the substantial cost of materials to produce such power meters can be a major concern.

These and other limitations of the prior art will become apparent to those of skill in the art upon a reading of the following descriptions and a study of the several figures of the drawing.

Summary

In some implementations, a gasket, set forth by way of example and not limitation, includes a housing having a plurality of openings operative to receive a plurality of prongs of a power connector for an appliance. At least one sensor is operative to sense at least one characteristic of an environment. A transmitter is operative to transmit one or more signals derived from the at least one sensed

characteristic, where the transmitted signals are capable of being received by a receiving device. A power circuit is operative to provide power from the electric current to the at least one sensor and the transmitter.

In various example implementations of the gasket, the sensor can be operative to sense at least one characteristic of an electric current flowing through at least one of the prongs. A converter circuit can be used convert one or more sensed analog voltages to the one or more signals that can be provided as digital data signals. The power circuit can be coupled to at least one conductive terminal that conductively contacts at least one of the prongs and creates an electrical connection between the terminal and prong, such that the terminal provides at least a portion of the electric current to the power circuit. In some implementations, the power circuit can be capacitively coupled to at least one of the prongs such that at least a portion of the electric current is provided to the power circuit. The gasket can include at least one ring of material provided around one or more of the openings, where the ring has a magnetic permeability operative to concentrate a magnetic field generated by electric current flowing through the at least one prong. For example, the sensor can be a Hall effect sensor, where the sensor can measure an intensity of the generated magnetic field and convert the measured intensity to the electrical signal representative of the intensity. In some implementations, the gasket housing can be separate from and physically coupled to an appliance connector housing, and the sensor and the power circuit can be integrated on a single flex board provided between a top cover and a bottom cover of the gasket housing, where the gasket can further include a ferrite ring that is coupled to the flex board.

The gasket can further include a processor coupled to the sensor circuit and transmitter. A memory can be included that stores instructions governing operation of the gasket, and a standardized interface connector coupled to the memory can be operative to be connected to an electronic device that can provide configuration and programming of the instructions. The transmitter can transmit the one or more signals via wireless communication. The gasket can be coupled to memory operative to store the signals over time as data, and the transmitter can transmit the data in response to a

communication channel being available. In some implementations, the housing can include the power circuitry and at least one sensor can be included in a removable sensor module physically distinct from the housing, where the sensor module can be connected to the housing by one or more housing connectors. For example, the

5 connectors of the housing can be provided for a standardized interface and the sensor module can include a connector for that standardized interface. In some implementations, a removable module distinct from the housing can include sensors and/or memory for storing sensor data and/or storing programming instructions for the gasket. A plurality of sensors of a plurality of different types can be used, each type

10 for sensing a different environmental characteristic, and digital sensors and/or analog sensors can be used. In some implementations, one or more of the sensors can be positioned remotely from the housing and connected to the transmitter by a wire. Some implementations can include a location circuit operative to receive location signals and provide location information indicative of a physical location of the

15 gasket, the location information to be output by the transmitter.

The one or more signals can include sensor data signals representative of power consumption of the appliance. The gasket can be engaged with the power connector of the appliance while the power connector is connected to an electrical outlet. The electric current can be AC current from an electrical outlet, and the power circuit can

20 convert the AC current to DC current for powering the at least one sensor and the transmitter. The power circuit can include a surge protection circuit that protects at least the power circuit from power surges and spikes in the electrical current, and which can include a power rectifier.

A method for sensing using a gasket, set forth by way of example and not

25 limitation, includes providing a housing including a plurality of openings operative to receive a plurality of prongs of a power connector of an appliance. The method includes sensing at least one characteristic of an environment using at least one sensor coupled to the housing. One or more signals are transmitted using a transmitter included in the housing, where the one or more signals are derived from the at least

30 one sensed characteristic, and the transmitted signals are received by a receiving

device. Power from the electric current is converted to a form usable by the at least one sensor and the transmitter using power circuitry included in the housing.

In various example implementations of the method, the sensing can include sensing at least one characteristic of electric current flowing through at least one of the prongs. The one or more transmitted signals can include information indicative of a power consumption of the appliance. The sensing can include measuring an intensity of a magnetic field generated by electric current passing through the at least one prong. At least one ring of material can be provided around the at least one opening to concentrate the magnetic field. The one or more transmitted signals can include information indicative of a power consumption of the appliance. The signals can be transmitted periodically to a receiving device that includes a remote server. The sensing gasket can be engaged with the prongs of the power connector of the appliance while the power connector is connected to an electrical outlet. Converting power can include generating DC power from the electric current, where the DC power is provided to drive at least the sensor and the transmitter.

In some implementations, a sensing apparatus for an appliance connector, set forth by way of example and not limitation, includes at least one circuit board including one or more openings operative to receive a corresponding number of prongs of the appliance connector. At least one sensor is coupled to the circuit board and is operative to sense at least one characteristic of an environment. A transmitter is coupled to the circuit board and is operative to transmit one or more signals derived from the at least one sensed characteristic, where the transmitted signals are capable of being received by a receiving device. A power circuit is coupled to the circuit board and is operative to provide power to the at least one sensor and to the transmitter, where the power circuit can receive electric current from at least one of the prongs of the appliance connector to drive the transmitter and the sensor.

In various example implementations of the sensing apparatus, the apparatus can include a gasket housing that is separate from and physically engaged with a housing of the appliance connector. The gasket housing can house the transmitter and the

power circuit, and the gasket housing can include a plurality of openings operative to receive a plurality of prongs of the appliance connector. The gasket housing can be engaged with the prongs while the appliance connector is connected to an electrical outlet, and the power circuit can generate DC power from the electric current flowing through the at least one prong. The DC power can be provided to drive at least the sensor and the transmitter. In other implementations, the sensing apparatus can include at least one circuit board provided within a housing of the appliance connector, where the transmitter and power circuit are coupled to the circuit board and are housed within the housing of the appliance connector.

In some implementations, the sensor can sense at least one characteristic of the electric current flowing through the prong, and the transmitted signals can include information indicative of a power consumption of the appliance. For example, the sensor can measure an intensity of a magnetic field generated by the electric current passing through the at least one prong of the appliance connector. The power circuit can be coupled to the at least one prong by a conductive contact or by a capacitive coupling. The transmitted signals can include information indicative of a power consumption of the appliance. The signals can be transmitted periodically to the receiving device that can include a remote server.

One or more processors can be coupled to the sensor and transmitter. The transmitter can transmit the signals via wireless communication. In some implementations, a housing can house the power circuitry, and the sensor can be included in a removable sensor module physically distinct from the housing, where the sensor module can be connected to the housing by one or more connectors on the housing. In some implementations, a housing houses the power circuitry, the sensor, and the transmitter, where sensor and the power circuit are integrated on the circuit board that is a single flex board provided between a top cover and a bottom cover of the housing, and at least one ferrite ring is coupled to the flex board.

A system, set forth by way of example and not limitation, includes a sensing apparatus coupled to an appliance connector of an appliance, where the appliance

connector is coupled to a power supply. The sensing apparatus includes at least one circuit board including one or more openings operative to receive a corresponding number of prongs of the appliance connector. At least one sensor is coupled to the circuit board and is operative to sense at least one characteristic of an environment. A transmitter is coupled to the circuit board and is operative to transmit one or more signals derived from the at least one sensed characteristic. A power circuit is coupled to the circuit board and is operative to provide power to the at least one sensor and to the transmitter, where the power circuit can receive electric current from at least one of the prongs of the appliance connector to drive the transmitter and the sensor. The system includes a receiving device located remotely from the sensing apparatus and operative to receive the signals from the transmitter. The receiving device provides the signals for use as data describing the at least one sensed environmental characteristic.

These and other combinations and advantages and other features disclosed herein will become apparent to those of skill in the art upon a reading of the following descriptions and a study of the several figures of the drawing.

Brief Description of Drawings

Several examples will now be described with reference to the drawings, wherein like components are provided with like reference numerals. The examples are intended for the purpose of illustration and not limitation. The drawings include the following figures:

Figure 1 is a block diagram of an example sensing system which can be used in some implementations of one or more features described herein;

Figure 2 is a diagrammatic illustration of an example implementation including one or more of the sensing gasket features described herein;

Figure 3 is a top view of an example gasket circuit board which can be used in some implementations;

Figure 4 is a block diagram illustrating a component system of a sensing gasket according to some implementations;

Figure 5 is a perspective view of an example of a sensing gasket that can be used in some implementations;

5 Figure 6 is an exploded perspective view of an example implementation of a gasket;

Figure 7 is a side view of one example implementation of a gasket;

Figure 8 is a top plan view of an example implementation of a sensor module which can be used with some implementations of a gasket;

10 Figure 9 is a side view of an example implementation of a gasket and sensor module allowing connection of a sensor module to a gasket platform;

Figures 10 is a top view of an example implementation of a gasket circuit board in which a magnetic sensor is used;

15 Figure 11 illustrates an example implementation of a coupling between prongs and gasket circuitry using a metal strip or conductive brushes;

Figure 12 illustrates an example implementation of a coupling between prongs and gasket circuitry using conductive foam;

Figure 13 illustrates an example implementation of a coupling between prongs and gasket circuitry using a capacitive coupling;

20 Figure 14 illustrates another example implementation of a capacitive coupling between gasket circuitry and connector prongs;

Figure 15 is a schematic diagram illustrating an example power supply circuit suitable for some implementations of the sensing gasket;

25 Figure 16 is a diagrammatic illustration of the operation of the rectifier circuit example of Fig. 15;

Figure 17 is a block diagram of an example of circuitry which can be used in conjunction with one or more sensors;

Figure 18 is a schematic diagram of an example surge protection circuitry which can be used in some implementations of the sensing gasket;

5 Figure 19 is a flow diagram illustrating an example method of processing digital sensor values by gasket circuitry;

Figure 20 is an perspective exploded view of an example implementation showing a physical construction of a gasket;

10 Figure 21 is a top view of an example implementation of the flex circuit board; and

Figure 22 is a block diagram illustrating an example implementation of a gasket in which multiple sensors are connected to the gasket.

Description of Embodiments

One or more implementations described herein pertain to sensing
15 characteristics related to a connector of an appliance. In some implementations, a sensing apparatus includes a circuit board and/or housing that includes one or more openings through which prongs of an appliance connector can be inserted. One or more sensors in communication with the sensing apparatus can sense environmental characteristics, such as an electric current flowing through at least one of the prongs of
20 the appliance connected. A transmitter of the sensing apparatus can transmit signals based on the sensed characteristics. A power circuit of the sensing apparatus can provide power from the electric current to sensing apparatus components such as the sensors, sensor circuit, and transmitter.

In some example implementations, the sensing apparatus can be included in a
25 gasket that is slipped on the prongs of a power connector such as an AC plug of an appliance, which in turn is connected to a power supply, such as an electrical outlet. For example, the gasket can be integrated with various types of sensor transducers to

measure a wide variety of environmental characteristics, including characteristics related to the power connector. In some implementations, the gasket can measure the current drawn through a prong in the plug using magnetic sensing such as Hall sensing, and can convert that measurement to digital format. For example, each of
5 multiple gaskets can continuously calculate the energy consumed by the appliance via the associated power connector over a particular or specified period of time, and can transmit the measured sensed consumption as data to a centralized device. In some implementations, the centralized device can be a server or other electronic device which can process and interpret aggregated data received from multiple gaskets, each
10 gasket monitoring a different appliance.

A gasket or other sensing apparatus can accommodate a variety of different sensor transduction devices. For example, some gasket implementations can include a platform component including circuitry used to perform functions other than the sensing function, such as a power supply, controller, transmitter, and antenna.
15 Various sensing devices can be removably connected to the platform component to provide various types of sensor functionality.

In some implementations, a gasket can function as a power meter that is small, unobtrusive, and low cost to produce. The gasket can also sense other characteristics of the appliance and/or environment in which the gasket is located. In some
20 implementations, the gasket can measure power consumption by measuring the current that is drawn through the appliance without inserting a measuring device in series with appliance in the path of the current. Due to small size and low cost, a gasket can be used in conjunction with each of a large number of appliances to provide aggregate data describing the sensed conditions of the appliances. On a server
25 level, this data can be organized and analyzed to produce increased value. One or more features of the sensor gasket can be useful when used to measure power consumption of a connected appliance. This can be a significant step in movement toward green energy and power conservation due to the importance of individual consumer awareness of how the consumers are using energy. For example,

availability of sensed data on a level of individual appliances allows consumers to easily determine how to reduce their power consumption.

As used herein, an “appliance” or the like refers to any electric or electronic device having a connector which can be engaged by the sensor gasket to monitor environmental characteristics related to the connector and/or environment. Non-limiting examples of appliances include desktop computers, laptop or netbook computers, tablet computers, personal digital assistants (PDAs), media players, cellular telephones, printers, stereos or audio output devices, televisions, telephones, home appliances and devices (refrigerator, toaster, dishwasher, coffee maker, clothes washer and/or dryer, etc.), air conditioners, heaters, fans, or any other device. The appliance may include a connector having one or more “prongs,” which can be any prongs, pins, extensions, conductors, or other conductive male connector protrusions of an appliance connector through which current can flow.

Figure 1 is a block diagram of an example sensing system 10 which can be used in some implementations of one or more features described herein. In this example, the sensing system 10 includes one or more appliance connectors 12 including one or more sensing features described herein, where the connectors 12 can each be connected to a corresponding mating connector 14. A data collector 16 can be used in some implementations to receive data transmitted by the appliance connectors 12 which is related to environmental characteristics sensed by sensors in association with the connectors. In some implementations of system 10, one or more data collectors 16 can be used locally to the appliance connectors 12 to receive data sent by the connectors 12, and the data collectors 16 can send received data to a centralized server 18 which processes data aggregated from multiple appliance connectors 12.

In some implementations, appliance connector 12 can be or include a plug head 19, such as a power plug head connected to a power cord 13 and used to provide power to an appliance connected to the plug head via the cord 13. For example, such a plug head 19 can be mated with a supply connector 14 providing power. In some implementations, the appliance connector 12 can be a male connector and the supply

connector 14 can be a female connector such as a socket in an electrical outlet or other receptacle, e.g., a wall outlet commonly provided on interior walls of buildings, or a socket provided on a power extension cord or power strip. In other implementations, the appliance connector 12 can be a female connector and the supply connector 14 can be a male connector. Other implementations can use other types of appliance connectors instead of a plug head 19, such as any of various connector types for providing an electrical connection. Furthermore, the appliance connector can be a connector that provides power to the appliance as well as communicating other signals, such as data (commands, parameters, etc.).

Sensing functionality described herein is provided by a sensing apparatus associated with an appliance connector 12. In some implementations, one or more of the sensing features described herein are provided by a sensing apparatus at least partially housed in a gasket 20 that has a separate housing from the housing of an appliance connector 12 and physically couples to, attaches to, or otherwise engages with the housing of the appliance connector 12. In one example, the gasket 20 includes one or more openings and can be slipped over prongs 22, 24, and 26 on plug head 19, where the plug head 19 is in turn plugged into the corresponding supply connector 14 such as socket 40 with corresponding openings 32, 34 and 36, thereby connecting circuitry within gasket 20 to hot, neutral, and ground connections of the outlet 14, respectively. The ground connection corresponding to prong 26 and socket opening 36 can optionally be included for some implementations. It is noted that outlets 14 standard to the USA are shown in Fig. 1, though any country's or other type of power outlet or socket standard can be used. In some example implementations, the plug head 19 with gasket 20 can be plugged into a top socket for outlet 40, into a bottom socket as shown in outlet 42 with plug-head/gasket 44, or in both sockets as shown in outlet 46 with plug-head/gaskets 48 and 50. In some implementations, the plug head 19 and gasket 20 can be plugged into a power strip, electrical power extension cord, power adapter, or other power receptacle or adapter.

The gasket 20 can include functionality for sensing one or more environmental characteristics of an environment. In certain examples, the environment surrounds a

sensor and in other examples the sensor may surround the environment or be proximate to an environment. In some examples, a sensed environmental characteristic can be a sensed characteristic of electric current drawn through the appliance connector 12. Other characteristics can alternatively or additionally be
5 sensed, such as temperature of the connector or air near the gasket, air pressure in the environment, and/or other characteristics, as described below.

In other implementations, the gasket 20 can be attached to an appliance connector 12 in other ways. For example, the gasket may be attached to one or more sides of a housing of the appliance connector 12 and have contacts routed to the
10 connector prongs.

In some implementations, the sensing apparatus and sensing functionality can be integrated into the appliance connector 12. For example, a sensing apparatus can be implemented by components housed within the housing of the appliance connector 12 and there need not be a separate gasket engaged with the appliance connector 12.
15 For example, any or all gasket components described herein, such as one or more circuit boards, one or more sensors, ring of ferrite material, circuitry, processors, memory, and other components can be integrated into the housing of the appliance connector 12. In some examples, one or more gasket components can be integrated into the connector housing near the prong-end of the housing, similarly as if a gasket
20 had been engaged with the prongs at that end of the housing. For example, a sensor and sensor ring can be positioned relative to prongs of the connector similarly as described herein for gasket implementations. In some implementations, the gasket components can be positioned anywhere within the housing of connector 12.

The gasket 20 can in some implementations include components to enable
25 communication to provide information related to the environmental characteristics sensed by the gasket 20. This information can be transmitted to other systems or devices via wireless communication. For example, wireless circuitry can be included in or connected to gasket 20 to transmit data that is collected by the gasket to centralized data collector 16 and/or server 18. In other implementations, gasket 20

can transmit data via wired communication, such as via one or more cables, traces, etc.

The data collector 16 can be any device that receives the data sent by one or more gaskets 20 provided on associated connectors 12. Data collector 16 can collect aggregate data from multiple such gaskets 20. For example, data collector 16 can be a device capable of processing the received data to provide actionable information, such as a computer server or other electronic device. In some implementations, data collector 16 can be a device that collects gasket sensor data locally and then re-transmits the data via a communication protocol to a non-local centralized server 18. For example, the data collector can provide received signals to a server 18 for use as data describing one or more sensed environmental characteristics. In some examples, data collector 16 can be a small computer or other device which can provide local processing and then transmit the results of that local processing to a centralized server 18 via wireless or wired communication. For example, the collector can be a plug computer 52 that plugs directly into an outlet receptacle 54 similarly to the appliance connector 12. In one example, receptacle 54 can be a different receptacle in a location near enough to one or more gaskets 20 to enable communications with those gaskets 20. Plug computer 52 can provide standard computing features in a small space, and can for example include a CPU or other processor, memory (e.g., flash memory and/or dynamic memory), network capability, etc. In some examples, the plug computer 52 can operate on a reduced or compact operating system. One example of a commercially available plug computer is the SheevaPlug™ computer from Marvell Semiconductor, Inc. Other implementations can provide a variety of other types of collector 16 devices. Some implementations can provide a data collector 16 in or more of the gaskets 20.

Centralized server 18 can be included in system 10 in some implementations. Server 18 can be an electronic device such as a computer server, desktop computer, portable computer or device, or other device. Server 18 can be remote from the connector 12, gasket 20, and data collector(s) 16. The server 18 can receive data signals from one or more data collectors 16 at various locations which have

aggregated data from one or more sensing gaskets 20 at various other locations local to each data collector 16. For example, the data collector 16 can send the data signals via a standard protocol, wirelessly and/or through wired channels, using the Internet or private network, to be received by the centralized server 18. Server 18 can provide the signals for use by itself or other devices as data describing one or more sensed environmental characteristics. For example, server 18 can process the received data signals to determine the status of the monitored environmental conditions, such as current consumption of the appliances connected to the appliance connectors 12. The server 18 may also be able to determine whether an actionable result exists based on the processed data, and can take particular actions in some implementations. Such action can be, for example, providing information or alerts to users or other devices, and/or providing commands or signals back to the data collectors 16 and/or gaskets 20 to start, modify, and/or stop particular functions implemented by the data collectors and/or gaskets.

A variety of wireless communication protocols are suitable for the local wireless communication between the gaskets 20 and the data collector 16. In implementations having a power plug 12 and receptacle 14 as shown in Fig. 1, power can be drawn from the receptacle and so conservation of power may not be a constraint. Some implementations provide a small and thin gasket 20 and so the communication protocol can support a transceiver size and antenna requirements that can be accommodated in the space available. In some examples, a network architecture can be used that reduces layering, exposes hardware functions directly to applications and middleware, and/or includes a single unifying layer of abstractions that includes interpreted scripts and simple program processes. Some implementations can use a network protocol using radio communication, where a varied analog and digital interface is handled by different messages within the protocol. In some examples, the communication can be based on an existing communication protocol such as the 802.15.4 communication standard. Some implementations can, for example, use a ZigBee® networking protocol, which is built on top of the 802.15.4 standard and includes an application-specific communication

signaling protocol between devices (also referred to as mesh networking). Other protocols with similar functionality can alternatively be used. This type of capability can enable each gasket 20 to transmit information to another gasket in the vicinity, which in turn transmits the information to another gasket, ultimately relaying the data to the data collector 16 and/or server 18. Such implementations can, for example, increase the maximum distance between the furthest gasket and the collector, provided that there are gaskets located between the endpoints that relay the information.

Some implementations can use a network protocol offering features such as self-configuration and security. For example, these features can be incorporated into the networking protocol. Self-configuration can automatically establish an identity of a gasket 20 within the network, e.g., through the means of an internet protocol (IP) address, and/or establish communication to other gaskets 20 in the vicinity of the gasket that can accept data for relaying. Security features can include identifying a specific data collector 16 to which the gasket 20 should be sending data. This can avoid a possibility of a gasket sending data to an incorrect or unrelated data collector 16 within the range of the gasket 20, such as a different user's data collector 16. Another security feature can include encryption of the data during transmission to avoid unauthorized interception.

Figure 2 is a diagrammatic illustration of an example implementation 200 including one or more of the sensing features described herein. In this example, power can be distributed to an appliance that is plugged into an electrical outlet using an appliance connector with a gasket slipped over the prongs of the appliance connector. With reference to Fig. 2, an appliance 202 is electrically connected to a power supply connector such as an electrical outlet 204 by a hot wire 206 and a neutral wire 208. Gasket circuitry 210 is within a gasket engaged with the appliance connector and is also coupled to the hot wire 206 and the neutral wire 208.

Power is provided to appliance 202 through hot wire 206 connected to hot outlet opening 212, and neutral wire 208 is connected to neutral outlet opening 214. Power is provided to the gasket circuitry 210 by drawing power from hot wire 206 and

neutral wire 208, such that the gasket circuitry is connected electrically in parallel to the appliance 202. In this circuit configuration, the current drawn by appliance 202 flows through a segment 216 of hot wire 206 between the appliance 202 and the hot connection of the gasket circuitry 210. Segment 218 carries the cumulative current
5 drawn by appliance 202 and gasket circuit 210.

The current drawn by gasket circuitry 210 is independent of the current drawn by appliance 202. In some implementations, the hot wire 206 passes through an opening in the gasket housing the gasket circuitry 210. The current drawn by the appliance 202 can be measured by the gasket by determining the current passing
10 through hot wire 206. In some implementations, this current can be measured by measuring an electromagnetic field radiated by hot wire 206, as described below.

Figure 3 is a top view of an example circuit board 300 which can be used in some implementations of a sensing apparatus, including a sensing gasket as described herein. In this example, the circuit board 300 utilizes a round circuit board or
15 substrate 302 and in some implementations can include multiple openings to allow passage therethrough by a corresponding number of prongs of an appliance connector such that the prongs can be inserted into or otherwise connected to a power supply connector. For example, three openings 301, 302, and 303 can be used, where three prongs of a power connector such as an AC plug can be inserted through these
20 openings to connect to hot, neutral, and ground connections of an electrical socket, respectively. Other implementations can use a different number, configuration, and/or shapes of openings 301-303 depending on the configuration of connector prongs and socket openings.

In some implementations, a portion of the area of circuit board 300 can hold
25 platform circuitry 306, and another portion can hold sensor circuitry 308. Both the platform circuitry 306 and the sensor circuitry 308 can be powered by coupling to a hot terminal 312 and neutral terminal 314 which receive current from particular prongs of the appliance connector inserted through the openings. Various implementations for making this coupling and receiving this power are described

below with respect to Figs. 11-14. Platform circuitry 306 can be connected to the sensor circuitry 308 via a connection 315. The sensor circuitry 308 can include one or more sensors 310, such as sensors integrated on the circuit board 300 in some implementations. Various implementations can also or alternatively provide one or
5 more sensors 310 separately from and connected to the circuit board 300.

In the implementation shown in Fig. 3, a sensor 310 is included in the sensor circuitry 308 to sense one or more environmental characteristics. In some examples described herein, the sensor can sense one or more characteristics of current flowing through the hot conductor of the appliance prong 303. For example, a magnetic field
10 caused by the current can be sensed to derive the magnitude of current flowing through the connector over time. In some implementations, for example, the sensing gasket can sense other environmental characteristics instead of or in addition to sensing current. In various implementations, one or more sensors can sense one or more of a variety of different environment characteristics, including temperature,
15 pressure, electric and magnetic fields, vibration, movement, gas and vapor concentration, odor, power, audio sounds, visual images or colors or patterns, etc.

The sensor circuitry 308 and/or platform circuitry 306 can obtain one or more signals derived from the sensed characteristic sensed by the sensor 310 and provide one or more signals suitable to be transmitted from the gasket. In some
20 implementations, the platform circuitry 306 can include wireless transceiver circuitry 316 (functionally shown in Fig. 3) which is connected via a connection 318 to an antenna 320 to transmit the sensor-derived signals wirelessly. In some implementations, the antenna can also receive wireless signals, such as from data collector 16 and/or server 18. In some examples, the antenna 320 can be configured
25 to wrap around the periphery of the gasket circuit board 300 near the edge of the board, as shown. In other implementations, antenna 320 can be a straight or linearly-shaped conductor or be of a different shape or configuration, some examples of which are shown in Fig. 21. In yet other implementations, the functionality of the antenna 320 can be provided by an antenna integrated circuit chip. In some examples, antenna

chips provided by Fractus S.A. or Johanson Technology, Inc. can be suitable for some implementations.

Figure 4 is a block diagram illustrating a component system 400 of a sensing apparatus such as a sensing gasket according to some implementations. For example, in some implementations the components of the component system 400 can include circuitry such as platform circuitry 306 and/or sensor circuitry 308 as shown in Fig. 3. In other embodiments, the circuitry can be compartmentalized or divided in other ways or based on other functionality. In various implementations, one or more digital sensors 404 and/or one or more analog sensors 406 can be used to sense environmental conditions relative to the sensors or gasket. For example, in some implementations a single digital or analog sensor can be used, while in other implementations multiple digital and/or analog sensors can be used.

The system 400 can include a standard interface 408 to connect the sensors 404 and/or 406. The interface 408 supports electrical connections from digital sensors 404 to a digital data bus 410 and a clock bus 412. The digital data bus 410 can receive sensor data describing one or more sensed environmental condition as sensed by the digital sensors 404. A clock signal on clock bus 412 can be generated by clock generator circuitry 414 which can generate the signal based on input from a real-time clock 416. The clock signal can be used by the digital sensors 404 to time the sensing of environmental conditions, among other timing functions used by the circuitry.

A controller 420 can be connected to the digital data bus 410, clock bus 412, real time clock 416 and a memory 422. For example, the controller 420 can be any suitable processor, such as one or more microprocessors, microcontrollers, application-specific integrated circuits (ASICs), logic gates, etc. Received sensor data can be processed by the controller 420 and resulting processed data placed on a data out bus 424. This output data can be sent to a data collector, server, or other device. For example, in some implementations the data can be output wirelessly by transceiver 426, which can be coupled to an antenna 428. For example, data can be transmitted periodically by the transceiver 426 based on environmental characteristics

continually being sensed by the sensors 404 and/or 406. The transceiver 426 can also be capable of receiving data wirelessly from other devices such as data collector 16 and/or server 18. For example, the received data can include program instructions, commands, parameters, and/or data, which can be placed on the data input bus 430 and provided to controller 420. Memory 422 can be utilized to store buffered incoming sensor data, program instructions for controller 420, parameters, or other data. In some implementations, controller 420 can include the memory 422 and/or additional memory to memory 422 as integrated memory for storing some or all of these types of data.

Power for component system 400 can in some implementations be provided from an AC voltage of a connected power source 430, which in some examples can be an electrical outlet 430 including a hot terminal 431, neutral terminal 432, and optionally an earth ground connection 433. The AC voltage 430 can be converted to a controlled DC voltage 436 utilizing power rectifier 438 and voltage regulator 440. The DC voltage can be used as a supply by the gasket circuitry, sensors, and any other components of the gasket. In other implementations, the component system 400 can receive power from different and/or additional power sources, such as batteries. In some implementations, power can be wirelessly transmitted from a remote source. For example, magnetic resonators can be used to transfer power wirelessly over distances.

Some implementations can alternatively or additionally use one or more analog sensors 406 providing analog sensor signals. Additional converter circuitry, such as a sample and hold and/or analog-to-digital converter, can be included in such implementations to convert the analog sensor signals to a digital format. For example, the output of analog sensor 406 can be coupled to an analog data bus 442, which in turn can be coupled to a sample and hold block 444 which uses the clock signal from clock bus 412 to sample the analog sensor signals. The sampled signals can be provided to an analog-to-digital converter that converts the received analog data to digital data for use by the controller 420. In various implementations, the analog-to-digital converter can be integrated in the controller 420, or the analog-to-digital

converter can be a separate component 446 which converts the analog signal from the sample and hold block 444 to digital data and provides that digital data on the digital data bus 410 to the controller 420.

In implementations using a wireless transceiver 426, any of a variety of wireless protocols can be used. In one example implementation, a ZigBee transceiver design can be used that is based on the 802.15.4 radio transmission protocol, such as a Zigbit™ chip from Atmel Corporation. In another example implementation, wireless standards such as Wi-Fi based n 802.11 can be used with components designed for that standard. In some non-limiting examples, programmable microcontroller (MCU) 2205 and Wi-Fi transceiver 2210 from Cypress Semiconductor Corporation can be used.

Figure 5 is a perspective view of an example of a sensing gasket 500 that can be used in some implementations. In the example of Fig. 5, gasket 500 can be slipped over prongs of a power connector such as an AC plug 501 connected to an appliance, where the plug is shown in phantom lines. The plug 501 is designed to connect to an electric outlet providing 120 V AC, 240 V AC, etc. In the example shown, prongs 502, 504, and 506 are inserted through openings 508, 510, and 512 of the gasket 500, respectively, such that the gasket 500 is seated against the housing of the plug 501. In some examples, prong 502 is the hot contact, prong 504 is the neutral contact, and prong 506 is a ground contact. The openings 508-512 are shown as shaped in rectangular or partially curved shapes to fit the prongs intended for use with the gasket. Other implementations can use circular or oval openings (as shown in Fig. 3) or openings having other shapes or dimensions. Some implementations can provide sufficiently large openings and/or flexible terminals or contacts to allow the gasket to fit many different plug or connector configurations. Furthermore, the plug 501 and gasket 500 are shown having an approximate wedge cross-sectional shape with a rounded protrusion on one side, but can be provided in other shapes or combinations of shapes in other embodiments, such as circular, rectangular, etc.

Figure 6 is an exploded perspective view of an example implementation of a gasket 600 similar to the gasket 500 shown in Fig. 5 or the gasket 20 shown in Fig. 1. Gasket 600 can include a housing that includes a top cover 602 and a bottom cover 606 and which house a circuit board 604. The top and bottom covers 602 and 606 can be made of plastic or other insulative material in some implementations. The circuit board 604 can be a thin substrate that includes circuitry implementing the gasket circuitry, sensor circuitry, and/or sensors described above. In some implementations, the circuit board 604 can be sandwiched between top cover 602 and interlocking bottom cover 606. Covers 602 and 606 and circuit board 604 can be square or rectangular in shape as shown, wedge-shaped as shown in Figs. 1 and 5, circular shaped, or otherwise shaped. Other implementations can include a single cover for a housing, which can be integrated with the circuit board in some implementations.

In some implementations, flex board or other thin circuit board substrate can be used for circuit board 604. In other implementations, circuit board 604 can be encapsulated in plastic or other material by producing a mold with circuit board 604 inside the encapsulation. When the gasket 600 is in use, conductive prongs of the appliance connector can be inserted through openings 610, 612, and 614 in the top plate 602, through aligned openings 620, 622, and 624 in the circuit board 604, and through openings 630, 632, and 634 in bottom plate 606. A coupling mechanism as described below can provide electrical connection between the inserted prongs of the AC plug and the gasket circuitry.

Figure 7 is a side view of one example implementation of a gasket 700. In some embodiments, one or more edges 702 of the gasket 700 can include various connectors, interfaces, indicators, and/or other I/O components. In some examples, an interface connector 704 can be provided for a standard interface such as USB or other type. The connector 704 can allow connection of the gasket to a variety of devices, such as to a computer, cell phone, or other electronic device to facilitate configuration and programming of the gasket code, parameters and/or operation, connection to additional memory, peripherals, or sensors, etc. A memory slot 706 can be provided to connect to separate, small form-factor memory modules such as micro-SD. LED

light indicators 708 can be provided to indicate any of a variety of gasket states, sensor states, I/O states, etc. A reset button 710 can be provided to allow reset of one or more states of the gasket 700. A sensor connector 712 can be used in some implementations to connect a separate sensor module that allows placement of one or more gasket sensors in a different location in the vicinity of the gasket 700.

Figure 8 is a top plan view of an example implementation of a separate sensor module which can be used with some implementations of a gasket described herein. In some implementations, the sensor circuit of the gasket can be constructed on the same circuit board substrate as the platform circuitry, as shown in the example of Fig. 3, or in another substrate included in the housing of the gasket. In other implementations, the sensor circuitry 308 and platform circuitry 306 as shown in Fig. 3 can be provided on separate circuit boards in separate modules, and can be connected together as interlocking modules. For example, the sensor circuit 308 can be included in a small form factor module 800 having a circuit board 802 and a connector 804 on one side of the circuit board 802. Some implementations can provide a portion of the sensor circuit 308 in module 800 and another portion in the gasket. Connector 804 can in some implementations correspond to a standard interface 408 as shown in Fig. 4. For example, some implementations can allow sensor modules to be supplied by one or more additional suppliers which can connect to the standard interface connector on the gasket housing. Sensor circuit 806 can be integrated on the circuit board 802 of the sensor module 800, and can include one or more sensors in some implementations, or can connect to a separate sensor provided on board 802 or otherwise within a housing of the sensor module 800.

Module 800 can be connected to a connector of the gasket. In some implementations, the module 800 can be connected to connector such as a slot 712 on the side of the gasket 700 shown in Fig. 7. Some implementations can connect the sensor module 800 with a gasket using a cable or wire. The gasket 700 can include platform circuitry such that connector 804 makes electrical contact with that platform circuitry, e.g., via a standard interface 408 to a bus on the platform circuitry. By separating the sensor module and the gasket platform, a generic gasket platform can

be provided in the gasket. The generic gasket platform can be connected to a variety of multiple different sensor types by attaching the appropriate sensor module(s) to the platform, allowing different environmental characteristics to be sensed as appropriate to particular applications. In some implementations, multiple sensor slots 712 can be provided on the gasket 700, allowing multiple sensor modules 800 to be connected, where the sensors of the connected modules can be the same or of differing types. Some implementations can allow sensors to be connected to a gasket via a standard interface connector such as USB, memory card connector, etc. Various implementations can include other components in a sensor module 800 in addition to one or more sensors, such as processor(s), memory for storing sensor data, memory for storing program instructions for the processor(s), power supply, circuitry, etc. Furthermore, some implementations can use a similar removable module that does not include sensors or sensor circuitry and which includes one or more of the other components.

Figure 9 is a side view of an example implementation 900 of a gasket and sensor module allowing connection of a sensor module to a gasket platform. A sensor module 902 can include sensor circuitry similarly as module 800 of Fig. 8, and a gasket 904 includes platform circuitry and a cavity 906 provided in one side of the gasket 904. Electrical contact can be made between leads 908 on sensor module 902 with corresponding contacts 910 in the cavity 906 of gasket 904. In some implementations, the sensor module 902 can snap into the cavity 906 such that when the sensor module is snapped into place, the surface of sensor module 902 opposite to its leads is approximately flush with the corresponding surface of gasket 904, thus reducing the size of the overall gasket assembly.

Figure 10 is a top view of an example implementation of a circuit board 1000 which can be used in a sensing apparatus and in which a magnetic sensor is used. In some implementations, a gasket including circuit board 1000 is placed over the conductive prongs of an appliance connector, such as an AC plug head. This results in the prongs 1002 and 1004 extending through openings 1006 and 1008. In the described implementation, opening 1006 is designated as a "hot" opening and prong

1002 is designated the "hot" power conductor. Opening 1008 is designated as a "neutral" opening and prong 1008 is designated the "neutral" power conductor. In some implementations, a third opening 1010 and a third prong 1012 can be used, referred to as "ground." In some implementations, for example, the third opening
5 1010 on the gasket can correspond with the placement of a third prong on a three-prong plug.

A ring of material 1020 can be provided to surround the hot opening 1006, and a gap 1022 can be included in ring 1020. Ring 1020 can be made of a material that has the property of high magnetic permeability, such as a ferrite material. Current
10 travelling through prong 1002 induces a magnetic field and ring 1020 concentrates that magnetic field. This can increase the strength of the magnetic field for easier measurement as well as stabilize a signal sensed from the magnetic field by significantly reducing dependence on the distance between ring 1020 and prong 1002.

A sensor can be positioned to measure an intensity of the generated magnetic
15 field. In the described implementation, a Hall effect sensor 1024 can be mounted within gap 1022 of the ring 1020. For example, the Hall effect sensor 1024 can be positioned at a right angle to the magnetic field concentrated by the ring 1020. The magnitude of the magnetic field that is experienced by the Hall effect sensor 1024 can be detected by detection circuitry 1026, which can be included in the sensor circuitry
20 for example. The detection circuitry 1026 can be coupled to the Hall effect sensor 1024 through conductors 1028 and provides analog signals representative of the sensed magnetic field. The analog output of detection circuitry 1026 can be converted to a sensor signal in a digital data format by analog-to-digital data conversion circuitry 1032, which in turn can send the digital data signal to a transceiver such as a data
25 transceiver 1034. In some implementations, the transceiver 1034 can transmit the digital data signal wirelessly via an antenna 1035 to any data collector or server within suitable range.

Detection circuitry 1026, data conversion circuitry 1032, and wireless data transceiver 1034 can be driven by power generated by a power generation circuit

1040. Circuit 1040 can be a DC power generation circuit in some implementations. Circuit 1040 can convert AC voltage on appliance prongs 1002 and 1004 to a DC voltage in the range of operation needed for the gasket circuitry, such as 3V to 10V in some examples. In some implementations, the input voltage from prongs 1002 and 5 1004 is coupled to power generation circuit 1040 via conductive terminals 1044 and 1046. In one example, each terminal can be a conductive, flexible brush that brushes against or otherwise physically contacts an associated prong 1002 or 1004 while the gasket is slipped over the plug prongs through openings 1006 and 1008. In other implementations, other types of couplings can be used to provide voltage to the power 10 generation circuit 1040, as described below.

Figures 11-14 are side views of various implementations providing a coupling between the prongs of the appliance connector and circuitry of the sensing apparatus (such as a gasket) using power from the prongs. Fig. 11 illustrates an example implementation 1100 of a coupling that is a conductive physical conductive contact 15 between prong and conductive terminal using a metal strip or conductive brushes. Conductive prongs 1102 and 1104 provide voltage and current and can be the hot and neutral prongs of a plug, for example. The circuit board 1106 of the gasket can include gasket circuitry as described above. Openings 1108 and 1110 are provided in the circuit board 1106 through which the prongs 1102 and 1104 extend. Terminals 20 such as metal strips or brushes 1120 and 1122 are mounted on circuit board 1106 and connected to circuitry provided on the circuit board. The brushes 1120 and 1122 can be positioned to protrude sufficiently into corresponding openings 1108 and 1110, respectively, such that when prongs 1102 and 1104 are inserted into the openings 1108 and 1110, contact is made between the brushes and the prongs. In some 25 implementations, the brushes 1120 and 1122 can be flexible enough to bend in response to the prongs being inserted, establishing firm contact. Some implementations also can position brushes on additional sides of the openings 1108 and 1110, such as brushes 1121 and 1123 as shown in Fig. 11. In some implementations using a ferrite ring provided around one or more openings 1108 and 30 1110, similarly as described for Fig. 10, the brushes 1120 and 1122 can be positioned

directly over or on the ring if, for example, the ring is provided with an insulator at the points of contact, such as insulating ink, paint, or other coating. Alternatively, the ring can be positioned on the opposite side of circuit board 1106 to the brushes.

In some implementations, other conductive contacts can be used instead of strips or brushes. In some examples, spring-loaded conductive contacts can be positioned similarly to the two brushes 1120 and 1122 or similarly to the four brushes 1120-1123 shown in Fig. 11. For each spring-loaded contact, a plunger can be connected to a base with a spring where the plunger extends over the corresponding opening of the circuit board. This allows the plunger to retract away from the prong 1102 or 1104 when the prong is inserted, while maintaining contact with the prong. Spring-loaded contacts can be mounted on multiple sides of an opening and conductor in some implementations.

In other examples, ball bearing contacts can be used instead of brushes 1120-1123, which are mounted to the circuit board 1106 similarly to the brushes 1120 and 1122 and connected to the circuitry of board 1106. For each prong 1102 and 1104, a ball bearing can be placed in a ball bearing housing that includes a spring mechanism. The spring forces the ball bearing toward the prong and allows the bearing to be pushed away when a prong is inserted, maintaining contact between bearing and prong. Ball bearings can be mounted on multiple sides of an opening and prong in some implementations.

Fig. 12 illustrates an example implementation 1200 of a coupling using conductive foam. Openings 1202 and 1204 in circuit board 1206 can be filled with conductive foam 1208 and 1210, respectively. A slit or other small opening can be allowed through the foam to allow prongs 1212 and 1214 to be inserted therethrough. The conductive foam 1208 and 1210 establishes conductive physical contact with the corresponding prong 1212 or 1214 and can overlap the surface of the circuit board where contact is made to the circuitry on the circuit board 1206. In some implementations using a ring provided around one or more openings similarly as described for Fig. 10, the conductive foam 1208 and/or 1210 can be positioned

directly over or on the ring if the ring is provided with an insulator at the points of contact, such as insulating ink, paint, or other coating.

Fig. 13 illustrates another example implementation 1300 of a coupling between gasket circuitry and the connector prongs, in which a capacitive coupling is used. In this implementation, terminals connected to the gasket circuitry are not conductively contacted to one or more prongs (e.g., the conductive terminals are not extended beyond the ring into the openings for the appliance connector prongs). Instead, a circuitry terminal acts as one side of a capacitor and a prong acts as the other side of the capacitor, where a dielectric is provided between these sides to prevent conductive contact of terminal and prong and form a capacitor.

Contact 1302 can be mounted on a circuit board 1304 to the edge of an opening 1306 in the circuit board and is connected to gasket circuitry such as power generation circuit 1040. A layer 1308 can be deposited on the opening end of the contact 1302, which is a thin layer of material having high permittivity. In some non-limiting examples, the thickness of layer 1308 can be about 0.1 mm or less, and the relative permittivity can be about 1,000 or higher. In some examples, a material such as barium titanate (BaTiO_3) or lead zirconate titanate can be used. Optionally, layer 1308 can cover other sides of the contact 1302, such that an electrical connection can be made between the circuitry on circuit board 1304 and contact 1302 without layer 1308 being in that connection.

A coupling capacitor is formed between prong 1310 of the appliance connector (first conductive plate) and contact 1302 (second conductive plate), where layer 1308 functions as a dielectric layer positioned between the conductive plates. The neutral prong 1312 can be inserted in opening 1314 and can be electrically connected to the gasket circuitry using any of the implementations described above with reference to Figs. 11 and 12. For example, a conductive brush 1313 similar to those shown in Fig. 11 is shown in Fig. 13.

This implementation allows an AC input voltage on the appliance connector prongs to be capacitively coupled to the gasket circuitry including the power

generation circuit on the gasket, thus allowing power to be derived from the appliance connector to drive the gasket circuitry.

In some alternate implementations, gasket molding material or other material can act as a dielectric in a capacitive coupling, e.g. above or below the field concentration material of ring 1020 in a cross-sectional view of the board 1000 of Fig. 10.

Fig. 14 illustrates another example implementation 1400 of a capacitive coupling between gasket circuitry and the connector prongs. A contact 1402 is connected to the gasket circuitry on circuit board 1404. A high permittivity layer 1406 can coat the side and the top of the contact 1402. A layer of conductive foam 1408 can cover a part of the high permittivity layer 1406. When a hot prong 1410 is inserted through opening 1412, the conductive foam 1408 is compressed to ensure that an electrical contact exists between the prong 1410 and the high permittivity layer 1406. Thus a capacitive coupling is formed between prong 1410 and contact 1402 acting as conductive plates, with the high permittivity layer 1406 acting as a dielectric. Neutral prong 1412 can be inserted in opening 1414 and can be electrically connected to the gasket circuitry using any desired method, e.g., any of the implementations described above with reference to Figs. 11 and 12.

In some other implementations, the layer of conductive foam 1408 can be removed, allowing an air gap to exist between conductor 1410 and high permittivity layer 1406 and connecting in series another capacitor having air as the dielectric. Such an implementation may dramatically decrease the effective capacitance between hot prong 1410 and contact 1402 and in some implementations may result in insufficient coupling for proper operation of one or more gasket circuits.

Figure 15 is a schematic diagram illustrating an example power supply circuit 1500 suitable for some implementations of the sensing apparatus. Circuit 1500 includes a rectifier 1502 and a voltage regulator 1504 which collectively can generate DC power from an AC electric current. In some implementations, power supply

circuit 1500 can be included in the platform circuitry of a gasket as described above, e.g., in DC power generation block 1040 of Fig. 10, for example.

Power supply 1506 is a power source to which the appliance connector is connected, such as an electrical socket of an outlet. The neutral connection 1512 of the power supply is coupled to the ground node 1514 of the circuit 1500. The hot connection 1508 from the power supply is coupled to an input node 1510 of the power supply circuit 1500, such as via any of the coupling implementations described above with respect to Figs. 11-14.

Capacitor 1516 can be connected to couple input node 1510 to internal node 1518. The cathode of diode 1520 is connected to node 1518, and the anode is coupled to ground node 1514. The anode of diode 1522 is connected to node 1518, and the cathode is connected to output node 1524. Output storage capacitor 1526 is connected between output node 1524 and ground node 1514. Zener diode 1528 is connected in parallel with capacitor 1526 with its cathode coupled to output node 1524 and its anode coupled to ground node 1514.

The rectifier circuit 1502 rectifies the input voltage at node 1510 and stores a DC charge on capacitor 1526. The charge on node 1524 can be used as a power source to drive all or a subset of circuits on the gasket. The Zener diode 1528 clamps the voltage at a predetermined level, thereby keeping node 1524 from going above a desired voltage level.

The output of rectifier circuit 1502 is provided to an input of a voltage regulator 1504. The output node 1530 of voltage regulator 1504 is a DC voltage that is used to power circuits on the gasket.

In other implementations of the rectifier circuit 1502, the operation is similar as described above except that the input voltage can be capacitively coupled from the conductors of the appliance connector. Some example embodiments of such a connection are described above with reference to Figs. 13-14. In some capacitive-coupled implementations, a capacitor can be connected only between the hot

connection and node 1518. In other implementations, a capacitor can be additionally coupled between the ground node and the neutral node.

Figure 16 is a diagrammatic illustration 1600 of the operation of the rectifier circuit 1502 example of Fig. 15. The AC input voltage is represented by the sinusoidal waveform 1602. The internal node voltage at node 1518 is represented by waveform 1604. The output voltage at node 1524 is represented by waveform 1606. As waveform 1602 rises to a more positive voltage, waveform 1604 follows that voltage since it is coupled by capacitor 1516 of Fig. 15.

While the voltage on node 1518 is higher than the voltage on output node 1524, diode 1522 passes current. Therefore, waveform 1606 follows waveform 1604 to time point 1610. Beyond time point 1610, input waveform 1602 goes to a lower voltage. Waveform 1604 follows the voltage waveform 1602 since it is coupled by capacitor 1516. At this point, the voltage on node 1518 is lower than on node 1524, causing diode 1522 to no longer conduct current. Therefore, charge is trapped on storage capacitor 1526, maintaining a constant voltage at node 1524. These respective voltages are represented between time points 1610 and 1612.

At time point 1612, the voltage on node 1518 begins to go negative. This places diode 1520 into a state where it conducts current, thereby connecting node 1518 to ground 1514. For this reason, node 1518 is now maintained at ground level. Since the voltage on node 1524 remains higher than node 1518, diode 1522 remains non-conducting, and the voltage on node 1524 continues to remain constant. These respective voltages are represented between time points 1612 and 1614.

At time point 1614, input voltage at node 1510 begins to swing to more positive voltages again. The voltage on internal node 1518 is coupled high through capacitor 1516. Since the voltage on node 1518 is now higher than ground 1514, diode 1520 goes into a non-conducting state. When the voltage on node 1518 exceeds the output voltage at node 1524, diode 1522 goes into a conducting state, thereby bringing node 1524 to a higher voltage. This is the case until input voltage at node 1510 begins to swing low again, which in turn will cause node 1518 to swing low into

a lower voltage than node 1524. Diode 1520 will now go into a non-conducting state, trapping charge on output node 1524. These respective voltages are represented between time points 1614 and 1616.

The above describes rectifier circuit operation over one period of the AC input voltage cycle. When charge is drawn from node 1524 to drive circuitry on the gasket, the voltage on node 1524 will drop as well. Device sizes can be chosen such that following periods of the AC input voltage replenish the charge that was consumed by circuitry on the gasket.

Figure 17 is a block diagram of an example of circuitry 1700 which can be used in conjunction with one or more sensors. In some implementations, one or more components of circuitry 1700 can be included in a sensor circuitry block of the gasket as described above for sensing current flowing through appliance prongs, e.g., in detection circuitry 1026 and/or data conversion block 1032 of Fig. 10. Circuitry 1700 can include a sensor block 1702 and a converter block 1704. The sensing circuitry 1700 can be used with a sensing ring implementation as described above, for example. Other appropriate sensing circuitry can be used with other types and implementations of sensors.

Sensor block 1702 can be used to sense a magnetic field caused by current flowing in the appliance connector. For example, a ferrite ring having a gap can be positioned around the hot opening in the gasket circuit board, as shown in the example of Fig. 10. Sensor block 1702 can include a magnetic Hall effect sensor positioned inside that gap. The concentrated magnetic field produced in the ferrite ring due to the electric current flowing through the hot conductor of the appliance connector results in a voltage on output 1708 of the Hall effect sensor. In an example implementation, a Hall effect sensor such as the A1362 from Allegro MicroSystems, Inc. can be used. The Hall effect sensor can produce a particular voltage amount for every amount of current through the hot prong. In some implementations, the hot prong provides an oscillating AC voltage, and the resulting Hall sensor current on output 1708 oscillates as well.

The oscillating voltage on sensor output 1708 can be converted to a DC voltage using converting circuitry in converter block 1704. For example, the output signal on output 1708 can be input to a RMS-to-DC converter chip in block 1704. An example of a RMS converter chip is AD536A from Analog Devices, Inc. An output 1712 from
5 block 1710 can output the resulting DC voltage. As the current through the hot prong increases, the magnitude of oscillating output signal on line 1708 increases, which results in a corresponding increase in SRMS voltage on output 1712. In this way, the voltage on output 1712 is a measure of the current drawn by the appliance, whose hot prong passes current through the ferrite ring in the gasket.

10 The output signal on output 1712 can be connected to a controller 1720, such as a processor as described above with reference to Fig. 4. In some non-limiting example implementations, an ATmega PCI18F26K20 8-bit microprocessor can be utilized. In some examples, the input analog voltage on line 1712 can be connected to a pin on microcontroller 1720 that connects to an analog-to-digital converter and
15 generates corresponding internal digital data to process by the controller 1720. Other implementations can use one or more other types of processors, such as digital logic, ASIC, etc.

Figure 18 is a schematic diagram of an example surge protection circuitry 1800 which can be used in some implementations of a sensing apparatus. For example,
20 standard household power may have large intermittent spikes of short duration, which may exceed the maximum voltage tolerance of circuit components on the gasket, making them vulnerable to partial damage or failure. Surge protection circuit 1800 can reduce the vulnerability of such components. Surge protection circuitry 1800 can be implemented in a relatively small space and is suitable to be provided on compact
25 gaskets.

Rectifier circuitry 1802 can include components similar to the rectifier circuit 1502 described above with reference to Fig. 15. Protection circuitry 1804 can be used to protect circuits on the gasket from power surges. Protection circuitry 1804 is connected between hot prong 1806 and the neutral prong 1808 of the appliance

conductor, and can include three components connected in series in the described implementation.

The first component can be a thermistor 1810, which functions as a resettable fuse in the circuitry 1800. At room temperature, the series resistance of thermistor 1810 is low, e.g., typically less than about 3.8 ohms in some examples. As current through thermistor 1800 increases, its internal temperature rises, increasing its resistance exponentially. Therefore, an unusually high current through thermistor 1810 causes it to act like an open circuit or a blown fuse. When normal operation is restored, the thermistor 1810 returns to normal temperature, e.g., the fuse “resets” itself. The thermistor can be provided to withstand short voltage spikes, including spikes that are typically caused by lightning strikes. In some non-limiting examples, thermistor 1810 can operate normally at 450mA and trip at 675mA; during normal operation, less than 170mA can flow through the thermistor 1810. An example of a suitable thermistor for some implementations is 0ZRA1000FF1A from Belfuse, Inc.

A second component of the protection circuitry 1804 can be a bidirectional TVS (transient voltage suppression) diode 1812. Bidirectional TVS diode 1812 can be connected in parallel with the coupling capacitor 1816. The bidirectionality of diode 1812 is not necessary for surge protection, but may be needed for proper rectifier operation. When the voltage exceeds a normal operating voltage in either positive or negative polarity, the bidirectional TVS diode 1812 conducts current through an avalanche breakdown mechanism, thereby limiting the voltage across the capacitor 1816. Thus, TVS diode 1812 can protect the coupling capacitor 1816 from over-voltage by shunting current around the capacitor. In some non-limiting examples, the diode 1812 can operate normally at 170 volts, limit voltage to about 182 volts or less, and can handle a surge current of up to 5A. A non-limiting example of a bidirectional TVS diode is SMDJ170A from Littlefuse, Inc.

A third component of the protection circuitry 1804 can be a TVS diode 1814, which breaks down when the reverse bias exceeds a specified threshold, thereby conducting current and clamping the voltage to a specified level. In case severe faults

occur elsewhere on the circuit board, the TVS diode 2333 can clamp the voltage on the rectifier to safe levels, protecting the power supply and sensitive circuitry. In some non-limiting examples, the TVS diode 1814 can start to break down at 6-7 volts and clamps the voltage on node 1818 to less than 10V at 50A, where the maximum
5 forward surge current that can be handled by the diode is 70A.

In some implementations, in addition to protecting the gasket circuitry, the surge protection circuit 1800 also can provide a measure of surge protection to the appliance connected to the appliance connector. The appliance can be connected between the same hot and neutral nodes as the gasket circuitry. During a voltage
10 spike, TVS diodes 1812 and 1814 reduce the voltage input into the gasket circuits that is the voltage between hot and neutral prongs. At the same time, thermistor 1810 decreases in resistance, thereby decreasing the current into the gasket circuits. During a short spike, the voltage between the two conductors is clamped since TVS diodes 1812 and 1814 react more quickly than thermistor 1810. During this interval of time,
15 the connected appliance is protected due to the clamping of the voltage. However, in the case of longer spike duration, the thermistor will increase in resistance, thereby increasing the voltage between the prongs. At this point, the gasket circuits are protected but the voltage on the appliance is no longer clamped. In some alternative implementations, the thermistor can be placed in series with the appliance to limit the
20 current, but this configuration may not be suitable for some gasket designs.

Figure 19 is a flow diagram illustrating an example method 1900 of processing digital sensor values by gasket circuitry. For example, the sensor values can be provided in a digital data signal provided from a sensor and/or other circuitry and received by one or more processors such as the controller 420 shown in Fig. 4, and the
25 processor(s) can implement process 1900. Instructions for the processor to implement the process may be stored, for example, in the memory 422 or other available storage. A software implementation for method 1900 can include but is not limited to firmware, resident software, microcode, etc. Some implementations can take the form of a computer program product accessible from a computer-usable or computer-
30 readable medium providing program code for use by or in connection with a

computer, processor, or any instruction execution system. For the purposes of this description, a computer-usable or computer readable medium can be any apparatus that can contain, store, communicate, propagate, or transport the program for use by or in connection with the instruction execution system, apparatus, or device. The
5 medium can be an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system (or apparatus or device) or a propagation medium. Examples of a computer-readable storage medium include a semiconductor or solid-state memory, magnetic tape, a removable computer diskette, a random access memory (RAM), a read-only memory (ROM), a rigid magnetic disk and an optical disk.

10 In some implementations of method 1900, discrete digital RMS values are received as a function of time and are stored in a double buffered array, and the values are processed to reflect a unit of energy consumed per unit time. In the implementation described in Fig. 19, a first set of received sensor values are buffered and then averaged to a resulting average value that is transmitted, and a second set of
15 the next received sensor values are similarly buffered while the first set is being processed and transmitted, where the second set is to be averaged and transmitted similarly to the first set. In other implementations, a single array can be used to store received and/or processed sensor data.

Some implementations can receive an analog RMS input signal from sensor
20 circuitry and convert the analog signal to a digital value with a sample and hold circuit and analog-to-digital converter, as described above for Fig. 4. For example, the sample and hold circuit 444 can trigger intervals controlled by the clock generator 414. In one non-limiting example, the clock can trigger a sample and hold event every 1 millisecond.

25 In step 1902, a count variable N is initialized to zero. In step 1904, a digital value is received, e.g., from an analog-to-digital converter. In step 1906, the digital value X_N is stored in a first array. For example, the array can be implemented in memory 422. In step 1908 the count variable N is incremented. In step 1910, the process checks whether N has reached a maximum count value for the first array. For

example, the first array can have a maximum count value of $N = 16$ in some implementations (for holding 16 values in the first array), or some other value depending on the desired amount of stored values to average at one time. If N has not reached the maximum count value, then the process returns to step 1904 to receive
5 another digital value.

If N has reached maximum count value, then the process can simultaneously continue to steps 1912 and 1920. In step 1912, the stored values in the first array are averaged. In some implementations, the values can be averaged using a moving average method or algorithm. For example, the following average formula can be
10 used:

$$CA[i+1] = X[i+1] + (i * CA[i]) / i+1$$

where CA is a moving cumulative average, X is a value, and i is a count variable incremented for each value in the array. This type of average can reduce the amount storage space required in determining an average from stored values. Other averaging
15 methods can be used in other implementations.

After step 1912, step 1914 transmits the averaged value using a transceiver, such as a wireless transmission to a data collector 16 or server 18. In some implementations, the averaged value can be stored (e.g., in a third array) until a predetermined number of averaged values have been determined, and then the
20 predetermined number of values can be transmitted together in a single transmission event every predetermined time interval. The amount of values stored can be based on the specific implementation. This branch of the process then ends for the current iteration.

Once N has reached maximum count value as determined in step 1910, then the
25 process also performs another branch in which a second array is used to store the next set of received values. The process can continue from step 1910 to step 1920 at the same time that the process is averaging the values stored in the first array in step 1912, or at a different time in alternate implementations. In step 1920, a digital value is

received, and in step 1922, the digital value X_N is stored in a second array that can be implemented in memory 422, for example. The second array can be the same size as the first array in some implementations. In step 1924, the count variable N is incremented, and in step 1926 the process checks whether N has reached a second maximum count value associated with the second array. In some implementations, the second array can have a maximum count value that is double the maximum count value of the first array, e.g., a maximum count value of 32 in implementations in which the first array maximum count value is 16. If N has not reached the maximum count value, then the process returns to step 1920 to receive another digital value. If N has reached the second maximum count value, then the process can simultaneously continue to steps 1928 and 1902. In step 1928, the stored values in the second array are averaged, e.g., similarly as the values in the first array as described above. In next step 1930, the averaged value can be stored or transmitted using a transceiver similarly as the averaged value in step 1914. This branch of the process then ends for the current iteration. Furthermore, once N has reached maximum count value as determined in step 1926, then the process also returns to step 1902 to reset the counter N and to begin storing values in the first array. Thus the process can continue from step 1910 to step 1920 and store values into the second array at the same time that the process is averaging the values stored in the first array in step 1912, and similarly store values in the first array while averaging values in the second array. In this manner, data can be processed from one of the two arrays while new data is stored in the other array. In some implementations, fewer or additional arrays can be used.

The resulting averaged data values can be transmitted (e.g., in a data packet) along with other information to a data collector 16 or server 18. The data values can be processed on the data collector or server to determine the sensed condition. For example, in the implementations described above the data values represent sensed current consumption by the appliance as measured through the appliance connector. A server can, for example, take the square root of the value and multiply by a unit conversion factor, with the result representing an average amount of energy used per unit time over the predetermined time interval between each transmission by the

gasket. The resolution of measurement can be adjusted to a desired level by altering the number of data values with which a single averaged data value is calculated. For example, by storing fewer measurements X_N in the array and then calculating the moving average value, the resolution of energy measurement is increased at the expense of requiring more data to be transmitted from the gasket, and vice versa.

It should be noted that the operations of the process 1900 can be implemented in the order of operations shown, in a different order, and/or some of the operations performed simultaneously where appropriate.

Figure 20 is an perspective exploded view of an example implementation 2000 showing a physical construction of a gasket including one or more features described herein. In some implementations it is desired that the gasket be thin enough not to interfere with the mechanism that holds the appliance connector in the supply connector such as an electrical outlet. For example, a thickness for the gasket in some implementations can be about 3 mm. Some implementations can also provide the gasket with a cross-sectional area that can fit within the surface area of the appliance connector such as a standard AC plug.

In a described example, the gasket can include a top molded plate 2002 and a bottom molded plate 2004 of a housing, with a flex circuit board 2006 positioned between these plates. The top and bottom plates can be made of plastic or other insulating material, for example. Top plate 2002 can include an opening 2010 at a relative location of a hot prong of an appliance plug, an opening 2012 to receive a neutral prong, and an opening 2014 to receive a ground prong. A spacer 2016 can include an opening sized to the hot prong and can be surrounded by a ferrite ring 2018 having a gap 2019. The spacer 2016 and ring 2018 can be inserted in the opening 2010 of the top plate 2002.

Flex circuit board 2006 can include a terminal or flap 2020 positioned for the neutral prong and a terminal or flap 2022 positioned for the hot prong of the appliance connector. Flaps 2020 and 2022 can be coated with a conductive material and extend beyond the ferrite ring 2018 into the opening receiving the respective prongs. The

ferrite ring 2018 can be coated with a dielectric, thereby avoiding electrical contact with flap 2022. In this manner, flap 2022 can act as a contact brush to contact the hot prong while flap 2020 can act as a contact brush to contact the neutral prong. The flex board material can be sufficiently flexible to bend as the prongs are inserted into the gasket openings, and sufficiently rigid to snap back into their neutral positions when the gasket is removed from the appliance plug.

A Hall effect sensor 2030 can be mounted on a flex board flap 2032, which can be twisted by 90 degrees as shown to be positioned inside the gap 2019 of ferrite ring 2018. Circuitry 2036 can be surface mounted on one or both sides of flex board 2006. The sides of top plate 2002 and bottom plate 2004 that face towards the flex board 2006 can be molded precisely to match the contour of the circuitry. For example, when pressed together, top plate 2002 and bottom plate 2004 can snap together with an interlocking mechanism on the edge of the gasket, holding in place flex board 2006, spacer 2016, and ferrite ring 2018.

Figure 21 illustrates an example of a top view of an implementation of the flex circuit board 2100 similar to the implementations shown in Fig. 20. Flex circuit board 2100 is a substrate which can be very thin (compared to regular FR4 printed circuit boards) and flexible, and on which circuit components can be mounted. The thickness of the flex circuit board can depend on material choices and the number of metal layers used. In addition, the flex board can be integrated into an injection molding fabrication process.

The outline of the flex board 2100 can be made to match the cross-sectional shape of a standard appliance plug, where in the example 2100 the board can be similarly-shaped to the wedge-shaped plug and gasket shape shown in Fig. 5. Opening 2102 and the opening 2104 can receive the neutral prong and earth ground prong of the adaptor connector, respectively. The hot prong of the adaptor connector can fit through the opening 2105. A Hall effect sensor 2107 can be located on flap 2106. The cut-out area 2108 of the flex board can be used to position a gapped ferrite ring 2110.

The ferrite ring 2110 can be any of a variety of shapes, including a circular ring as shown above in other implementations. Ferrite ring 2110 can alternatively be a rectangular structure as shown in Fig. 21. In some implementations, the rectangular ferrite structure 2110 may be more efficient in terms of space allocation than a circular structure. The opening in the ring 2110 can be large enough to accommodate a hot prong of the appliance connector. In one non-limiting example, the opening can be at least 7 mm long (longest dimension) and 4mm wide, and the gap 2112 in ring 2110 (or gap 1022 in circular ring 1020) can be about 1 mm and long enough to fit a Hall effect sensor.

Examples of various other component are also shown on flex board 2100 in examples of Fig. 21. Rectangular ferrite structure 2110 can be placed in the cut-away area 2108 of the circuit board 2100 such that the gap 2112 aligns with Hall effect sensor 2107 on flap 2106. In some implementations, flap 2106 can be folded along line 2120, thereby turning the surface of Hall effect sensor 2107 perpendicular to ring gap 2112. A surface-mounted microcontroller 2122, transceiver 2124, antenna chip 2126, and discrete circuit components can be mounted in the space available on flex board 2100.

Antenna chip 2126 can be space efficient and may require no ground plane. One non-limiting example of a suitable antenna chip is 1450AT43D100 from Johanson Technology, Inc. In some implementations, a less expensive antenna can alternatively be formed by using conductive traces on the flex board 2100. Two antenna designs 2130 and 2132 are shown as examples. In some implementations, such alternative antennas may cause the size of the gasket to be increased beyond the size of a standard plug.

In other implementations, silicon chips can be mounted directly on an insulating substrate, e.g. using a technique called chip-scale packaging. Alternatively, Micro-Electro-Mechanical Systems (MEMs) can be used to produce the ferrite ring functionality and gasket the circuitry. In some implementations, organic electronics can be used to construct the circuitry through a sequential process of printing layers of

functional dielectric, conductive, and semiconductor inks on thin flexible plastic or fabric substrates. Some implementations can produce gasket circuits by encapsulating the circuits in plastic or constructing circuitry between two molded plastic plates. Alternatively, the gasket boards can be encapsulated directly into an appliance connector.

Figure 22 is a block diagram illustrating an example implementation 2200 of a sensing apparatus, such as a gasket, in which multiple sensors are connected to the gasket. Gasket 2200 is connected to three different sensors 2202, 2204, and 2206. The sensors are connected to a standard interface bus 2210 through a multiplexer 2208. The interface bus 2210 is coupled to the gasket platform 2212 (such as a gasket circuit board). For example, in some implementations the multiplexer 2208, interface bus 2210, and gasket platform 2212 (such as a circuit board) can be provided within the housing of the gasket while one or more of sensors 2202 - 2206 are separate from the gasket and coupled to the gasket via a connector such as shown above for Figs. 7-9. One of more of such sensors can be made interchangeable such that the sensor can be disconnected and a different sensor and/or sensor type can be connected to the gasket circuitry. In some embodiments, one or more of the sensors 2202-2206 can be included in the gasket housing, e.g., sensor types that are useful for a wide array of applications.

In some implementations, the multiplexer 2208 can be used to select one of the sensors 2202-2206 from which to receive sensor data for processing at any given interval in time. For example, sensor 2202 can be read and processed during a first interval of time, sensor 2204 can be read and processed during a second interval of time, and sensor 2206 can be read and processed during a third interval of time. At the fourth interval of time, sensor 2202 can be read and processed again, and so on. This concept can be expanded to n sensors, where n intervals of time are sequentially read and processed, and where the resulting read frequency of any one sensor is sufficiently high to achieve the read resolution desired.

A sensing apparatus, such as a gasket, with one or more features as described herein can send sensor data to a receiving device such as a data collector 16 and/or server 18. For example, the gasket can collect current sensor data and calculate average values as described above. In some implementations, packets transmitted from the gasket can include a header that includes an IP address and media access control (MAC) address assigned to the gasket and identifying the gasket on the network. At the receiving device (e.g., data collector or server), a gasket's MAC address and IP address can be associated with the received average data by interrogating the header section of the received information packet.

In some implementations, the physical location of the gasket can be determined by a receiving device based on received sensor data. In some examples, one or more geographic attributes can be assigned to sensor data that is collected. For example, each gasket can be associated with a specific outlet receptacle 14 or other receptacle, and may be typically stationary in some implementations. Thus, a gasket IP address and/or MAC address can be associated with the location of a specific outlet when the gasket and plug are plugged into that outlet. Thereafter, the association of an IP address or MAC address can be associated with a specific physical location. One way that this can be accomplished is to make this association manually. Specifically, when the gasket is plugged in, a user can associate the gasket's outlet location with a known MAC address of the gasket or an assigned IP address of the gasket. In some implementations, this association can be automated by connected software or device to avoid potential errors that may occur when a gasket is unplugged from one outlet and plugged into another without making the corresponding changes to the associated physical location. Thus, if a user or receiving device has kept track of the location where a given gasket was placed and the particular appliance(s) connected to it, then the data received from the gasket can be associated with the location at which it was obtained and with the appliance pertinent to the measurements.

In some implementations, location circuitry can be included in a sensing apparatus, such as a gasket, to assist in determining the geographical or physical location of the gasket. The location circuit can receive location signals from one or

more sources and provide location information indicative of a physical or geographical location of the gasket. The location information can be transmitted by the transmitter to a receiving device such as a data collector or server. For example, in some implementations, global positioning system (GPS) co-ordinates can be used to identify the physical location of the outlet into which a gasket is plugged. In some examples, this can be accomplished by including a small GPS receiver chip within or connected to the gasket. Location information indicating the GPS-determined location of the gasket can be transmitted from the gasket to a receiving device. An example of such a chip having small size is the GNS7560 receiver chip from NXP Semiconductors. In some other examples, a ZigBee™ RTLS (Real Time Location System) can be utilized for the purposes of automatically mapping gaskets to their physical location. For example, an RTLS chip or circuit can be included in the gasket circuitry in some implementations. Either on demand or periodically, this chip can take measurements of time of arrival (TOA) or received signal strength (RSSI) from nearby reference sensors, whose locations are known. These measurements can be included in a data packet transmitted from the gasket to a receiving device (data collector or server). Software such as a location engine, e.g., residing on the data collector 16 or centralized server 18, can calculate the location of the gasket based on the TOA and RSSI data, along with known distances to and locations of the reference sensors. The resulting location can then be associated with the gasket's IP address or MAC address. An example of an RTLS locator chip is CC2431 from Texas Instruments Inc.

In addition, the received data can be time-stamped at time of arrival at the receiving device. Thus the data can be associated with the time, location and the appliance related to the sensed measurement. In some implementations, the gasket can timestamp measured data points at the time of measurement and before they are transmitted to provide increased precision and avoid a varying and/or unknown delay between the time of measurement and time of arrival of data at a receiving device. For example, the real-time clock 416 can be used to provide the time for the timestamps. The timestamp information can be included in the data packet that is

transmitted from the gasket, to be extracted and used as the timestamp by the receiving device.

In some implementations, the sensing apparatus, such as a gasket, can include recovery mechanisms to overcome temporary network failure. The averaged data points can be stored in memory during network failure instead of transmitting them, e.g., by increasing the allocated amount of memory available on the gasket. The oldest data in memory can be overwritten by newly measured data if the memory becomes full, allowing the latest set of data to be stored on the gasket (e.g., with associated timestamps), ready to be transmitted when network communications are restored.

Some implementations enable the receiving device to identify the appliance connected to a sensing apparatus, such as a gasket, by examining received data and identifying unique characteristics of a transient current of the appliance when it is first powered on. For example, this identification can be made on the receiving device after the data on the gasket has been transmitted by matching incoming data with a table or database on the receiving device storing previously-received data that corresponds to specific appliances. In this manner, the data can be used to identify an electronic “signature” of the appliance as a means of identifying that appliance.

Another feature used in some implementations of the sensing apparatus, such as a gasket, is remote software or firmware updating. In one example implementation, program instructions to manage the update can be stored in a part of the gasket's memory that is not part of the operating system. During a remote software update, the gasket can continue to operate by taking instructions from that code. The new software can be transmitted wirelessly, and overwrite the existing code with the new code.

It should be noted that the diagrams described herein may illustrate functional blocks and that the components may be arranged differently. For example, memory 422 of Fig. 4 may be integrated into the controller 420 and/or other components may be integrated or separately connected. These and other design variants will be

appreciated by those of ordinary skill in the art. It should also be noted that various features and implementations for gaskets described herein can apply to other forms and types of sensing apparatus consistent with the disclosure.

Although various examples have been described using specific terms and devices, such description is for illustrative purposes only. The words used are words of description rather than of limitation. In addition, it should be understood that aspects of various other examples may be interchanged either in whole or in part. It is therefore intended that the claims be interpreted in accordance with their true spirit and scope and without limitation or estoppel.

10 WHAT IS CLAIMED IS:

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Claims

1. A gasket comprising:

a housing including a plurality of openings operative to receive a plurality of
5 prongs of a power connector for an appliance;

at least one sensor operative to sense at least one characteristic of an
environment;

a transmitter operative to transmit one or more signals derived from the at least
one sensed characteristic, wherein the transmitted signals are capable of being
10 received by a receiving device; and

a power circuit operative to provide power from electric current received from
at least one of the prongs to the at least one sensor and the transmitter.

2. The gasket of claim 1 wherein the at least one sensor is operative to sense at
least one characteristic of an electric current flowing through at least one of the
15 prongs.

3. The gasket of claim 1 further comprising a converter circuit operative to
convert one or more sensed analog voltages to the one or more signals that are
provided as digital data signals.

4. The gasket of claim 1 wherein the power circuit is coupled to at least one
20 conductive terminal operative to conductively contact at least one of the prongs and
create an electrical connection between the at least one terminal and the at least one
contacted prong, wherein the at least one terminal provides at least a portion of the
electric current to the power circuit.

5. The gasket of claim 1 wherein the power circuit is capacitively coupled to at
25 least one of the prongs, wherein the capacitive coupling provides at least a portion of
the electric current to the power circuit.

6. The gasket of claim 1 further comprising at least one ring of material provided around at least one of the plurality of openings, wherein the ring of material has a magnetic permeability operative to concentrate a magnetic field generated by electric current flowing through the at least one prong, and

5 wherein the at least one sensor includes a Hall effect sensor, wherein the at least one sensor is operative to measure an intensity of the generated magnetic field and convert the measured intensity to the electrical signal representative of the intensity.

7. The gasket of claim 2 wherein the one or more signals include sensor data
10 signals representative of power consumption of the appliance.

8. The gasket of claim 1 further comprising at least one processor coupled to the transmitter, and wherein the transmitter transmits the one or more signals via wireless communication.

9. The gasket of claim 1 wherein the gasket is operative to be engaged with the
15 power connector of the appliance while the power connector is connected to an electrical outlet, wherein the electric current is AC current from an electrical outlet, and wherein the power circuit is operative to convert the AC current to DC current for powering the at least one sensor and the transmitter.

10. The gasket of claim 1 wherein the housing includes the power circuitry,
20 and wherein the at least one sensor is included in a removable sensor module physically distinct from the housing, wherein the sensor module is operative to be connected to the housing by one or more connectors provided on the housing.

11. The gasket of claim 10 wherein the one or more connectors of the housing are provided for a standardized interface and the sensor module has a connector for
25 the standardized interface.

12. The gasket of claim 1 wherein the housing includes the power circuitry, and further comprising a removable module physically distinct from the housing and

operative to be connected to the housing by one or more connectors provided on the housing, wherein the module includes at least one of: the at least one sensor, memory for storing sensor data, and memory for storing programming instructions for the gasket.

5 13. The gasket of claim 1 further comprising memory storing instructions governing operation of the gasket, and a standardized interface connector coupled to the memory, the standardized interface connector operative to be connected to an electronic device that is operative to provide configuration and programming of the instructions.

10 14. The gasket of claim 1 wherein the at least one sensor is a plurality of sensors, and wherein the plurality of sensors include sensors of a plurality of different types, each type for sensing a different characteristic of the environment.

 15. The gasket of claim 1 wherein the at least one sensor is a digital sensor.

 16. The gasket of claim 1 wherein the at least one sensor is an analog sensor.

15 17. The gasket of claim 1 wherein one or more of the at least one sensor is positioned remotely from the housing, and is connected to the transmitter by a wire.

 18. The gasket of claim 1 wherein the power circuit includes a surge protection circuit operative to protect at least the power circuit from power surges and spikes in the electric current, wherein the surge protection circuit includes a power rectifier.

20 19. The gasket of claim 1 wherein the gasket is coupled to memory operative to store the signals over time as data, and wherein the transmitter is operative to transmit the data in response to a communication channel being available.

 20. The gasket of claim 1 wherein the housing is separate from and physically coupled to an appliance connector housing, wherein the at least one sensor and the
25 power circuit are integrated on a single flex board provided between a top cover of the housing and a bottom cover of the housing, and wherein the gasket further comprises at least one ferrite ring that is coupled to the flex board.

21. The gasket of claim 1 further comprising a location circuit operative to receive location signals and provide location information indicative of a physical location of the gasket, the location information to be output by the transmitter.

22. A method for sensing using a gasket, comprising:

5 providing a housing including a plurality of openings operative to receive a plurality of prongs of a power connector of an appliance;

sensing at least one characteristic of an environment using at least one sensor coupled to the housing;

transmitting one or more signals using a transmitter included in the housing,
10 wherein the one or more signals are derived from the at least one sensed characteristic, and wherein the transmitted signals are received by a receiving device; and

converting power from electric current received from at least one of the prongs to a form usable by the at least one sensor and the transmitter using power circuitry included in the housing.

15 23. The method of claim 22 wherein the sensing at least one characteristic includes sensing at least one characteristic of electric current flowing through at least one of the plurality of prongs, and wherein the one or more transmitted signals include information indicative of a power consumption of the appliance.

24. The method of claim 23 wherein the sensing includes measuring an
20 intensity of a magnetic field generated by electric current passing through the at least one prong.

25. The method of claim 22 further comprising providing at least one ring of material around the at least one opening to concentrate the magnetic field.

26. The method of claim 22 wherein the gasket is operative to be engaged with
25 the plurality of prongs of the power connector of the appliance while the power connector is connected to an electrical outlet, and wherein converting power includes

generating DC power from the electric current, the DC power provided to drive at least the sensor and the transmitter.

27. The method of claim 22 wherein the one or more transmitted signals include information indicative of a power consumption of the appliance, and wherein the one or more signals are transmitted periodically to the receiving device that includes a remote server.

28. A sensing apparatus for an appliance connector, the sensing apparatus comprising:

at least one circuit board including one or more openings operative to receive a corresponding number of prongs of the appliance connector;

at least one sensor coupled to the circuit board and operative to sense at least one characteristic of an environment;

a transmitter coupled to the circuit board and operative to transmit one or more signals derived from the at least one sensed characteristic, wherein the transmitted signals are capable of being received by a receiving device; and

a power circuit coupled to the circuit board and operative to provide power to the at least one sensor and to the transmitter, wherein the power circuit is operative to receive electric current from at least one of the prongs of the appliance connector to drive the transmitter and the at least one sensor.

29. The sensing apparatus of claim 28 further comprising a gasket housing separate from and physically engaged with a housing of the appliance connector, wherein the gasket housing houses the transmitter and the power circuit, and wherein the gasket housing including a plurality of openings operative to receive a plurality of prongs of the appliance connector.

30. The sensing apparatus of claim 28 further comprising at least one circuit board included within a housing of the appliance connector, and wherein the

transmitter and power circuit are coupled to the at least one circuit board and are housed within the housing of the appliance connector.

31. The sensing apparatus of claim 28 wherein the at least one sensor senses at least one characteristic of the electric current flowing through the at least one prong, and wherein the one or more transmitted signals include information indicative of a power consumption of the appliance.

32. The sensing apparatus of claim 28 wherein the sensor measures an intensity of a magnetic field generated by the electric current passing through the at least one prong of the appliance connector.

33. The sensing apparatus of claim 28 wherein the power circuit is coupled to the at least one prong of the appliance connector by a conductive contact or by a capacitive coupling.

34. The sensing apparatus of claim 29 wherein the gasket housing is operative to be engaged with the plurality of prongs of the appliance connector while the appliance connector is connected to an electrical outlet, and wherein the power circuit generates DC power from the electric current flowing through the at least one prong, the DC power provided to drive at least the sensor and the transmitter.

35. The sensing apparatus of claim 28 wherein the one or more transmitted signals include information indicative of a power consumption of the appliance, and wherein the one or more signals are transmitted periodically to the receiving device that includes a remote server.

36. The sensing apparatus of claim 28 further comprising at least one processor coupled to the at least one sensor and to the transmitter, and wherein the transmitter transmits the one or more signals via wireless communication.

37. The sensing apparatus of claim 28 wherein a housing houses the power circuitry, and wherein the at least one sensor is included in a removable sensor module

physically distinct from the housing, wherein the sensor module is operative to be connected to the housing by one or more connectors provided on the housing.

38. The sensing apparatus of claim 28 wherein a housing houses the power circuitry, the at least one sensor, and the transmitter, wherein the at least one sensor and the power circuit are integrated on the circuit board that is a single flex board provided between a top cover of the housing and a bottom cover of the housing, and wherein the sensing apparatus further comprises at least one ferrite ring that is coupled to the flex board.

39. A system comprising:

a sensing apparatus coupled to an appliance connector of an appliance, the appliance connector being coupled to a power supply, wherein the sensing apparatus includes:

at least one circuit board including one or more openings operative to receive a corresponding number of prongs of the appliance connector;

at least one sensor coupled to the circuit board and operative to sense at least one characteristic of an environment;

a transmitter coupled to the circuit board and operative to transmit one or more signals derived from the at least one sensed characteristic; and

a power circuit coupled to the circuit board and operative to provide power to the at least one sensor and to the transmitter, wherein the power circuit is operative to receive electric current from at least one of the prongs of the appliance connector to drive the transmitter and the at least one sensor; and

a receiving device located remotely from the sensing apparatus and operative to receive the one or more signals from the transmitter, wherein the receiving device is operative to provide the one or more signals for use as data describing the at least one sensed environmental characteristic.

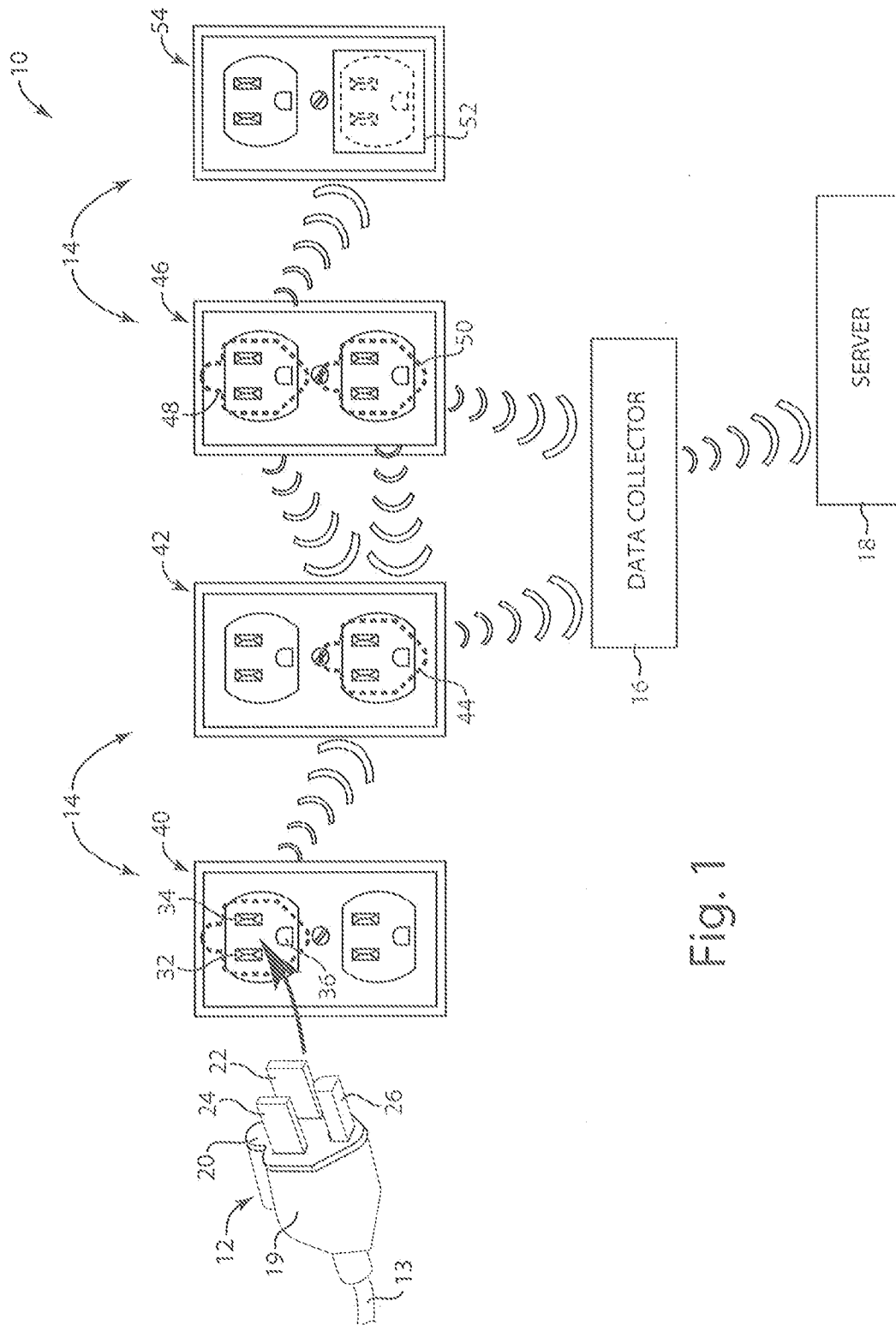
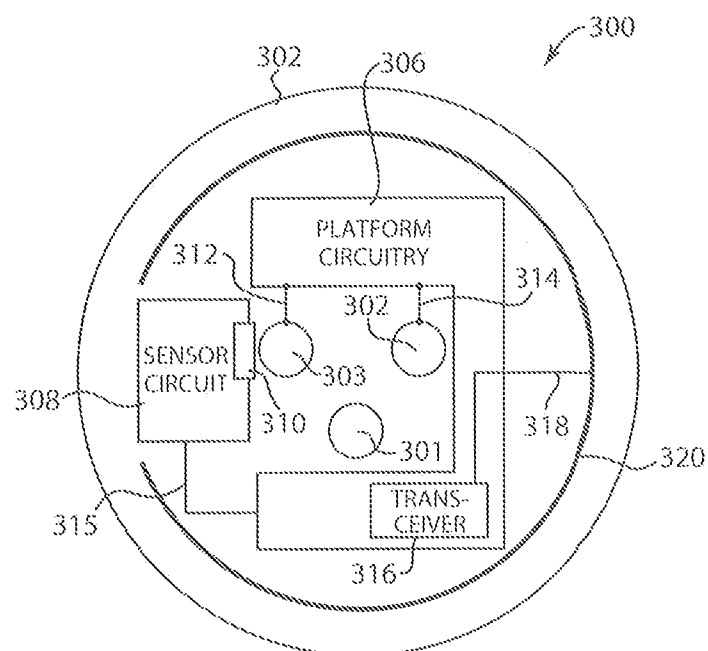
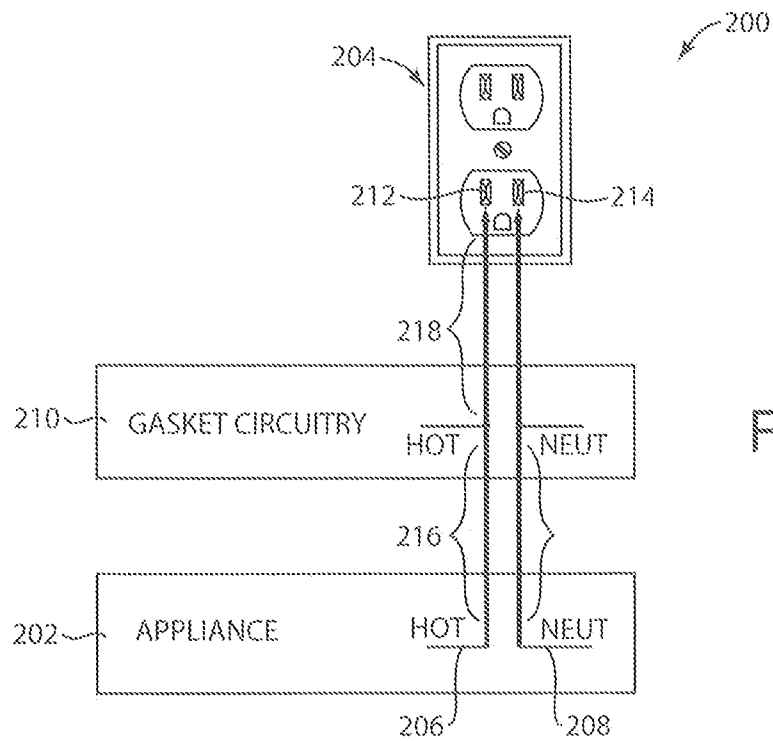


Fig. 1



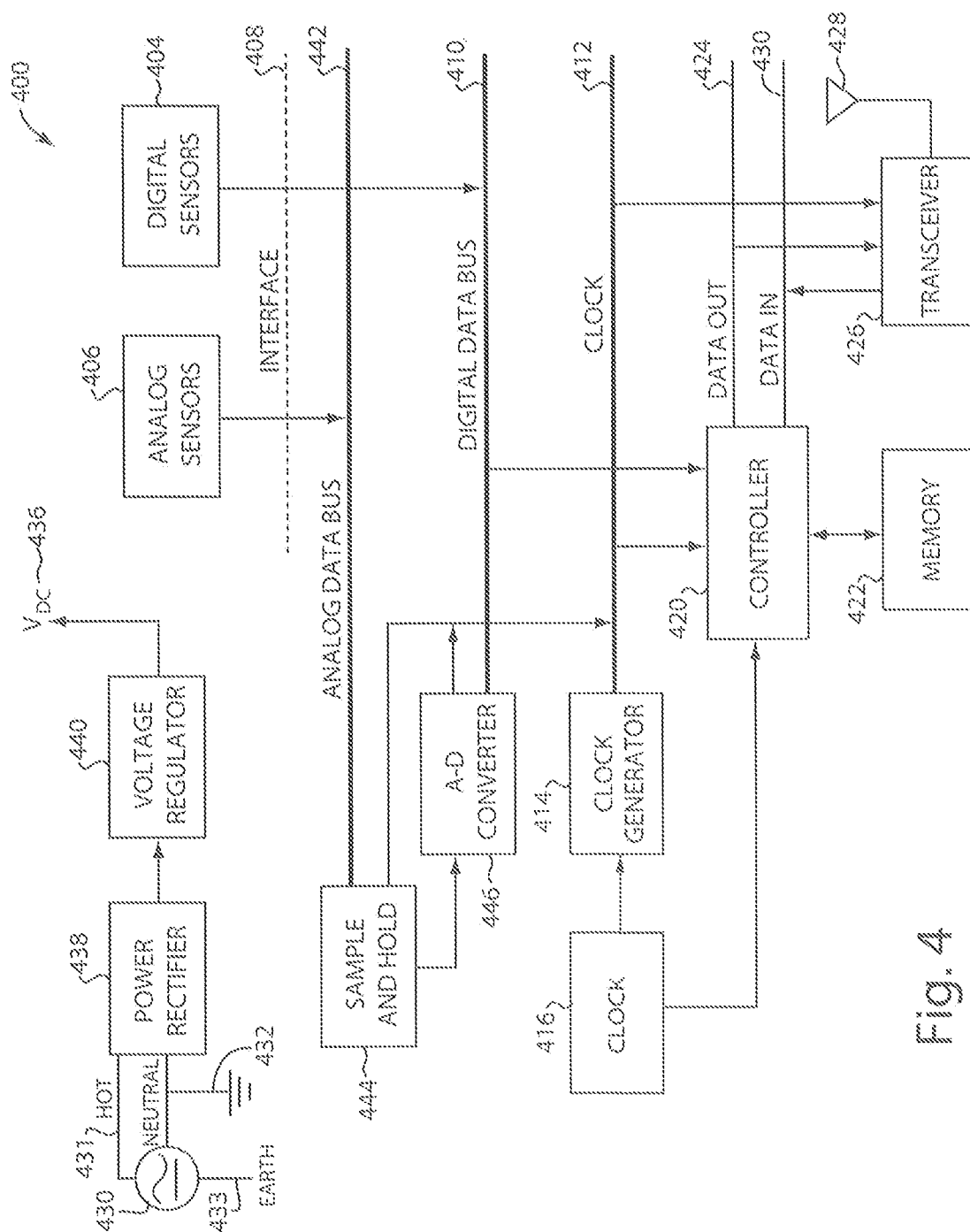


Fig. 4

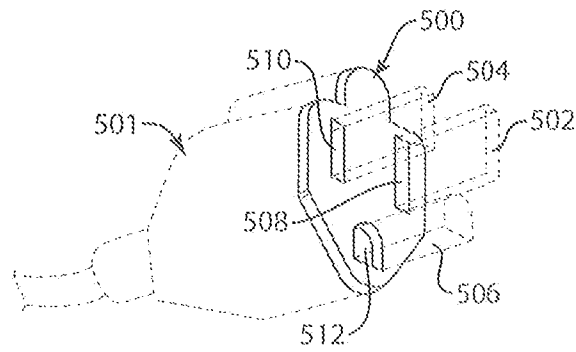


Fig. 5

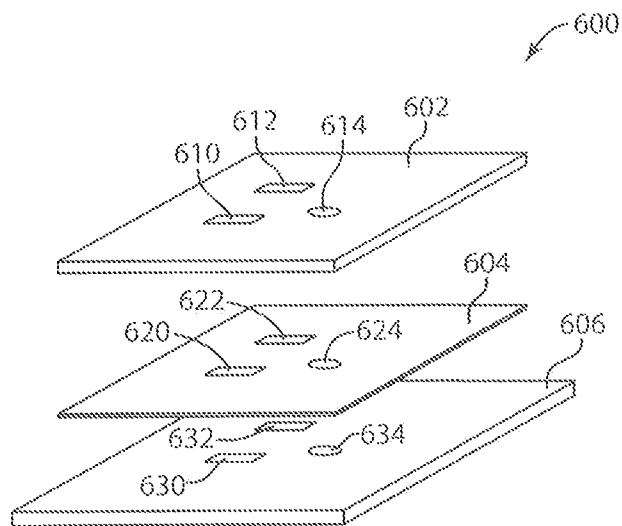


Fig. 6

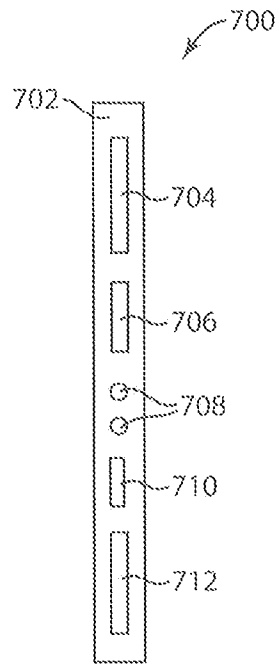


Fig. 7

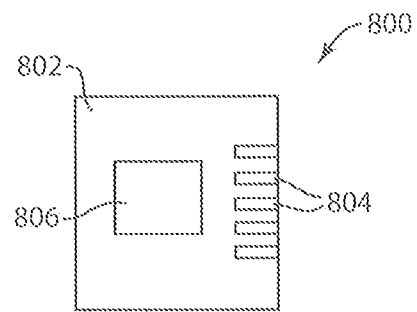


Fig. 8

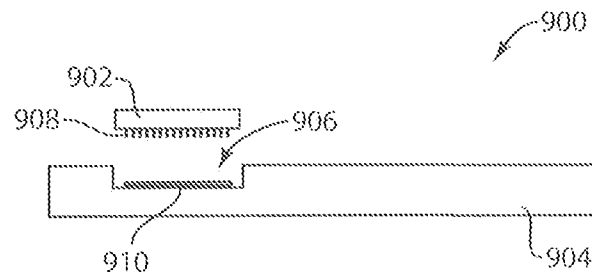


Fig. 9

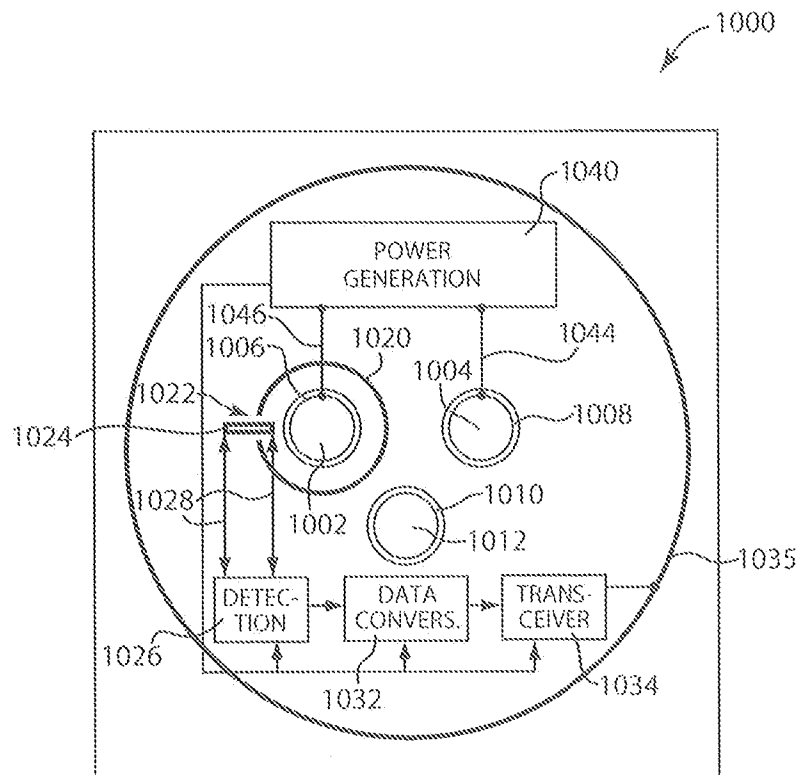


Fig. 10

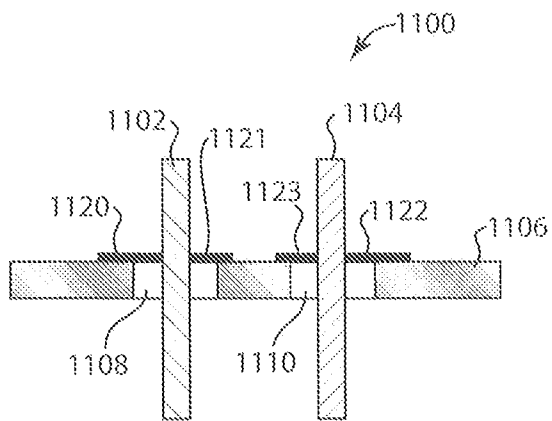


Fig. 11

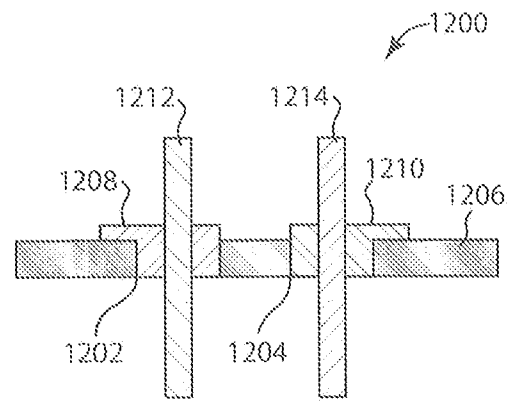


Fig. 12

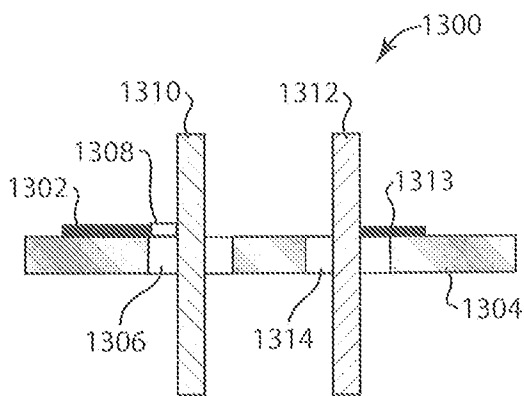


Fig. 13

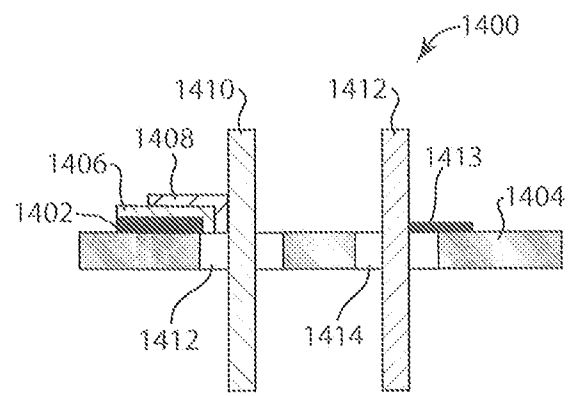


Fig. 14

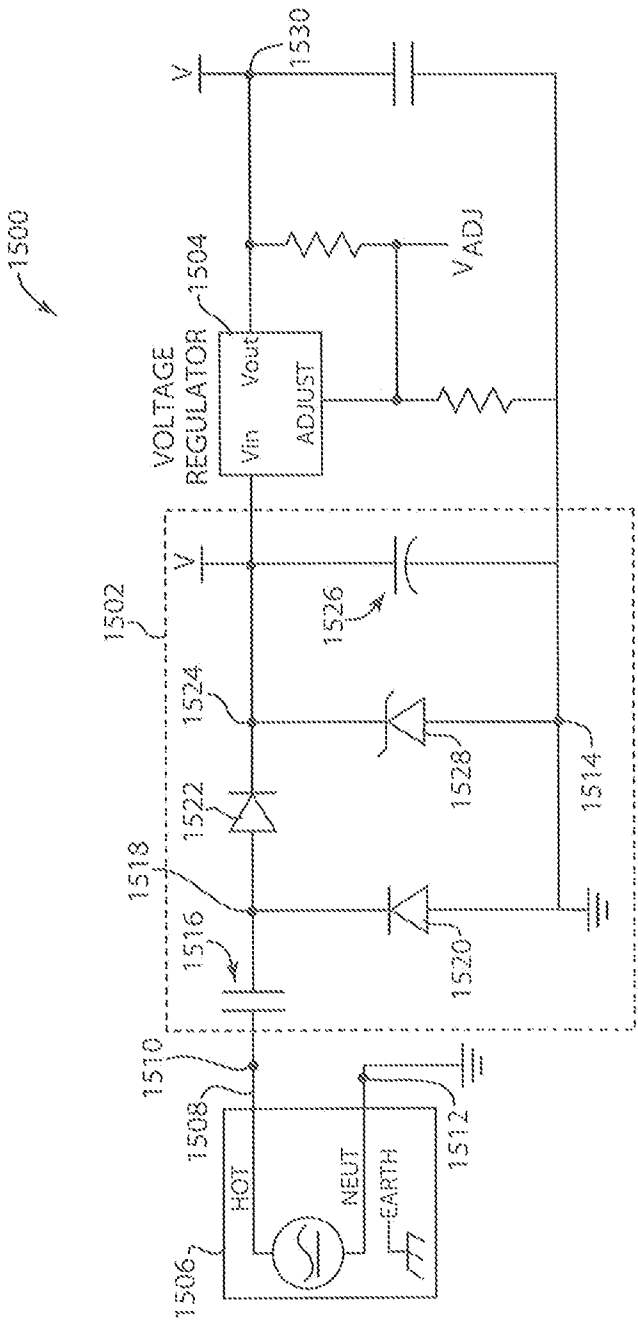


Fig. 15

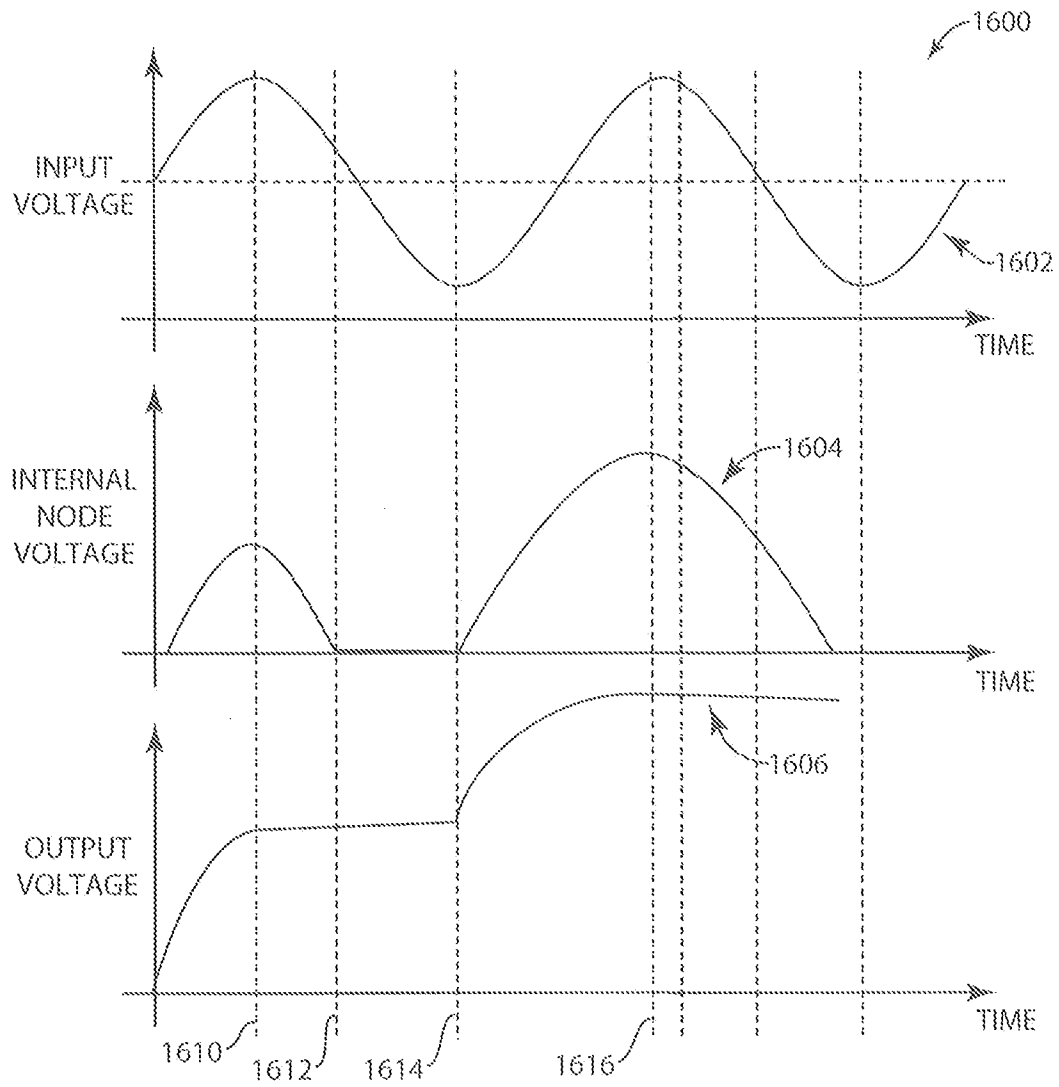


Fig. 16

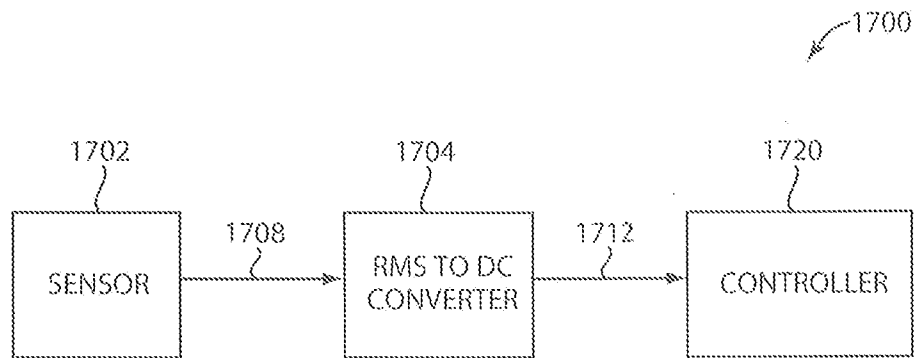


Fig. 17

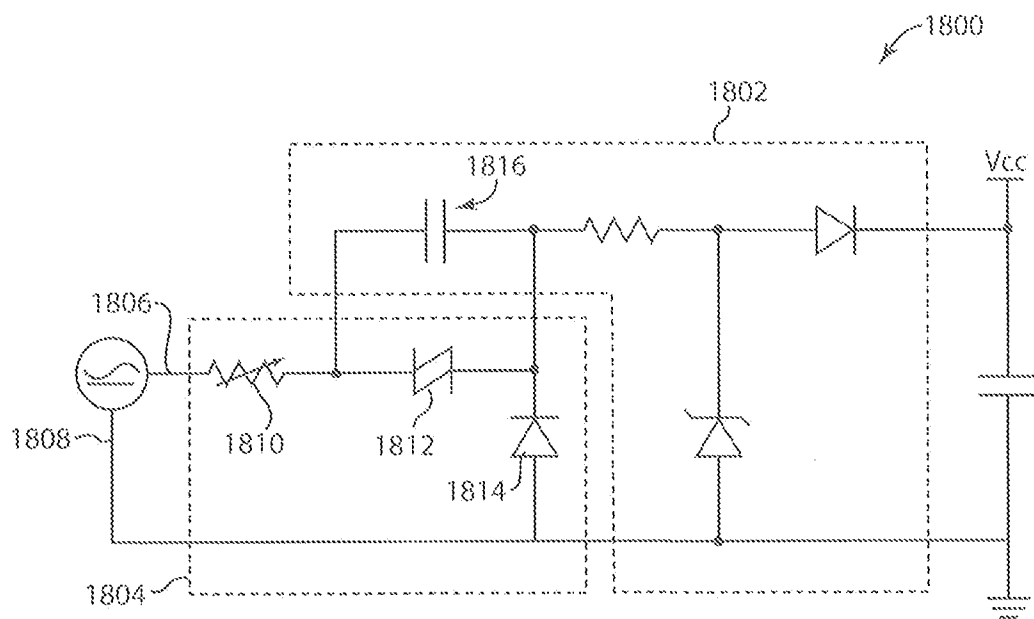
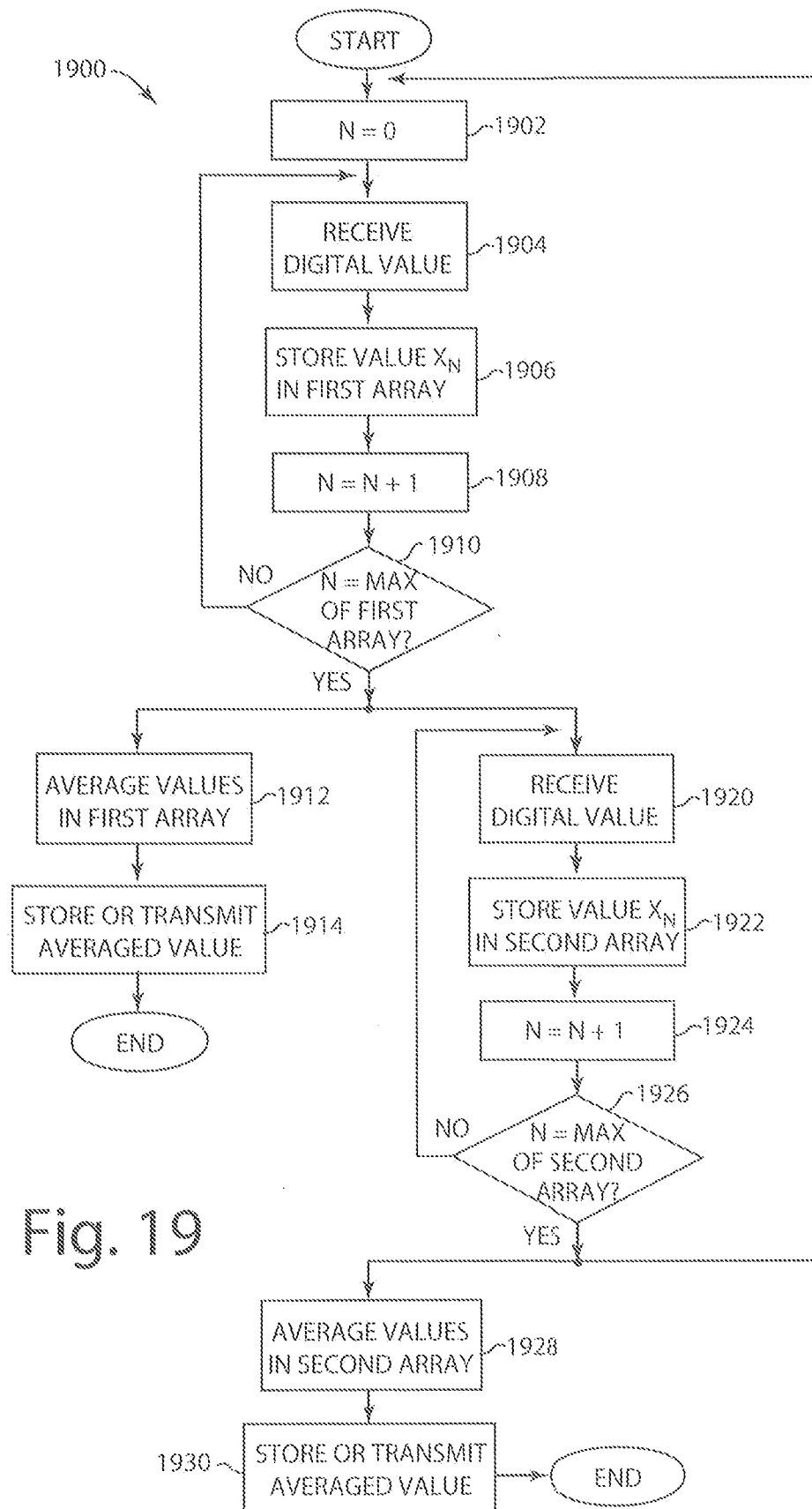


Fig. 18



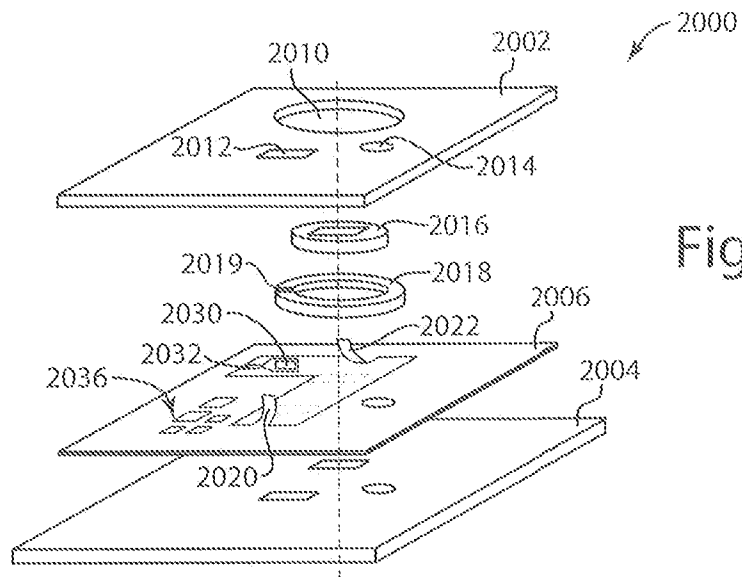


Fig. 20

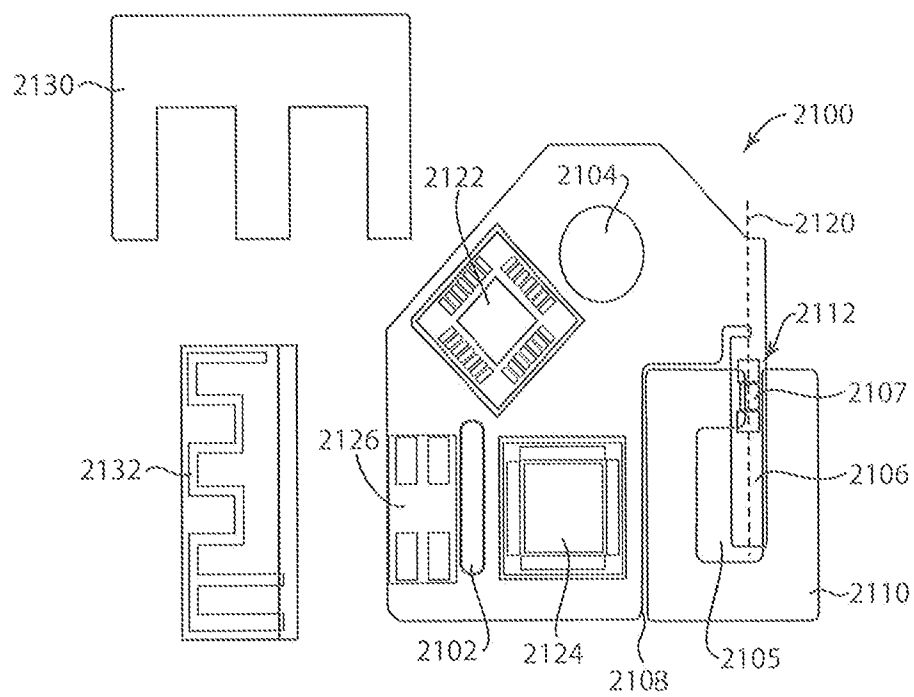


Fig. 21

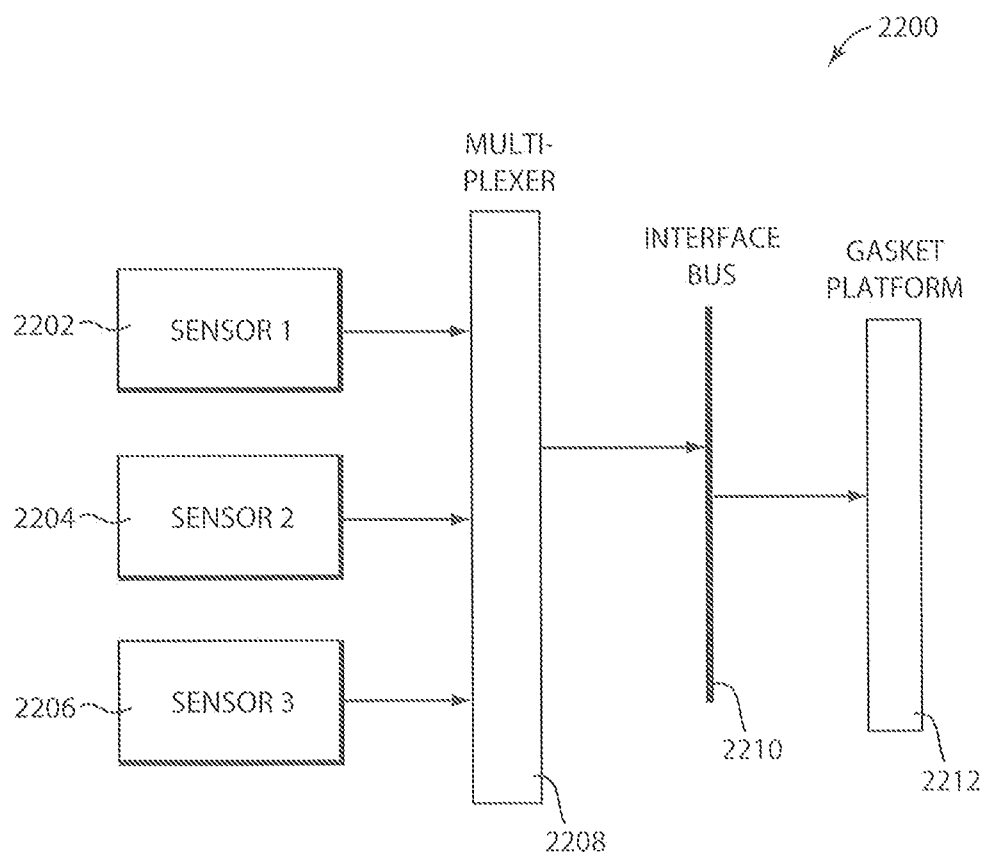


Fig. 22

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2013/026502

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G08B 1/08 (2013.01)

USPC - 340/538

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - G01R 11/00, 11/04, 11/32, 21/00, 21/133, 22/00; G06F 1/26; H02J 13/00 (2013.01)

USPC - 307/75, 326; 324/126, 142, 149, 156; 340/538

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G01R 21/1331, 22/063; G06F 1/26; G08B 1/08 (2013.01)

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

Google Scholar, Google Patents, Patbase

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011/0276289 A1 (PARK et al) 10 November 2011 (10.11.2011) entire document	1-39
Y	US 5,428,288 A (FOREMAN et al) 27 June 1995 (27.06.1995) entire document	1-39
Y	US 2011/0109301 A1 (JOHNSON et al) 12 May 2011 (12.05.2011) entire document	6, 25
Y	US 2008/0224861 A1 (MCNEELY et al) 18 September 2008 (18.09.2008) entire document	6, 9-13, 18, 25-26, 30, 34, 37
Y	US 2011/0014800 A1 (CHENG et al) 20 January 2011 (20.01.2011) entire document	20, 38
Y	US 2011/0316690 A1 (SIEGMAN) 29 December 2011 (29.12.2011) entire document	21

☐ Further documents are listed in the continuation of Box C.

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"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

30 April 2013

Date of mailing of the international search report

21 MAY 2013

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
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