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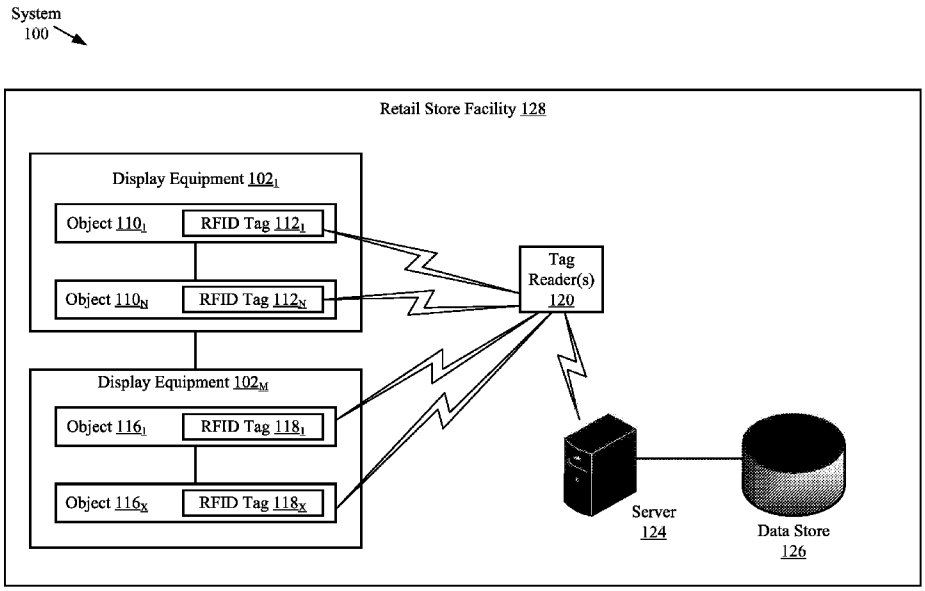


FIG. 1

(57) Abstract: Systems and methods for operating a tag. The method comprising: causing motion of a spherical permanent magnet which is disposed and freely movable in a three dimensional internal space of a non-magnetic hollow sphere located within the tag; using the spherical permanent magnet's motion to cause a change in a magnetic flux in a wire wrapped around at least a portion of the non-magnetic hollow sphere, where the change in the magnetic flux induces a current in the wire; and supplying the current to at least one device of the tag's internal electronic devices that is configured to facilitate at least one of an inventory count and an inventory security.

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SYSTEMS AND METHODS FOR PROVIDING A TAG WITH A MINIATURE ZERO POWER MOTION DETECTOR AND ENERGY HARVESTER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the benefit of U.S. Patent Application Serial No. 15/966,707 filed on April 30, 2018, the entirety of which is incorporated herein by reference.

BACKGROUND

Statement of the Technical Field

[0002] The present disclosure relates generally to tag based systems. More particularly, the present disclosure relates to implementing systems and methods for robust protection of item authentication, tracking and tracing against tag duplication.

Description of the Related Art

[0003] There are many types, sizes and prices of devices on the market that either detect motion or harvest energy power for electronics. For self-powering devices (e.g., Radio Frequency Identification ("RFID") chips), these solutions are all too large, too expensive or in the case of motion require constant power which doesn't exist. Devices such as piezo electric energy harvesters require weights, leverage or torsion on a fairly large piezo device.

SUMMARY

[0004] The present disclosure generally concerns implementing systems and methods for operating a tag. The tag comprises an RFID tag and/or an Electronic Article Surveillance component. The methods comprise: causing motion of a spherical permanent magnet which is disposed and freely movable in a three dimensional internal space of a non-magnetic hollow sphere located within the tag; and using the spherical permanent magnet's motion to cause a change in a magnetic flux in a wire wrapped around at least a portion of the non-magnetic hollow sphere. The change in the magnetic flux induces a current in the wire. The current is

then used to supply power to at least one device of the tag's internal electronic devices that is configured to facilitate at least one of an inventory count and an inventory security.

[0005] In some scenarios, the wire extends in a single direction along an outer surface of the non-magnetic hollow sphere, or is wrapped around the non-magnetic hollow sphere in at least two orthogonal directions. The current is generated from 3D motion of the spherical permanent magnet.

[0006] In those or other scenarios, the at least one device comprises a communications enabled device and/or an energy storage device (e.g., a rechargeable battery or a capacitor). The communications enabled device is supplied power only when the tag's magnetic current has indicated that the tag is in motion.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] The present solution will be described with reference to the following drawing figures, in which like numerals represent like items throughout the figures.

[0008] FIG. 1 is an illustration of an illustrative architecture for a system.

[0009] FIG. 2 provides an illustration of an illustrative architecture for a tag.

[0010] FIG. 3 is an illustration of an illustrative architecture for the energy harvesting circuit shown in FIG. 2.

[0011] FIG. 4 is an illustration of another illustrative architecture for the energy harvesting circuit.

[0012] FIG. 5 is an illustration of a hollow sphere with a spherical magnet enclosed therein.

[0013] FIG. 6 is an illustration of an illustrative architecture for a motion based electricity generator.

[0014] FIG. 7 is an illustration of another illustrative architecture for a motion based electricity generator.

[0015] FIG. 8 is a flow diagram of an illustrative method for operating a tag.

DETAILED DESCRIPTION

[0016] It will be readily understood that the components of the embodiments as generally described herein and illustrated in the appended figures could be arranged and designed in a wide variety of different configurations. Thus, the following more detailed description of various embodiments, as represented in the figures, is not intended to limit the scope of the present disclosure, but is merely representative of various embodiments. While the various aspects of the embodiments are presented in drawings, the drawings are not necessarily drawn to scale unless specifically indicated.

[0017] The present solution may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the present solution is, therefore, indicated by the appended claims rather than by this detailed description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope.

[0018] Reference throughout this specification to features, advantages, or similar language does not imply that all of the features and advantages that may be realized with the present solution should be or are in any single embodiment of the present solution. Rather, language referring to the features and advantages is understood to mean that a specific feature, advantage, or characteristic described in connection with an embodiment is included in at least one embodiment of the present solution. Thus, discussions of the features and advantages, and similar language, throughout the specification may, but do not necessarily, refer to the same embodiment.

[0019] Furthermore, the described features, advantages and characteristics of the present solution may be combined in any suitable manner in one or more embodiments. One skilled in the relevant art will recognize, in light of the description herein, that the present solution can be practiced without one or more of the specific features or advantages of a particular embodiment.

In other instances, additional features and advantages may be recognized in certain embodiments that may not be present in all embodiments of the present solution.

[0020] Reference throughout this specification to "one embodiment", "an embodiment", or similar language means that a particular feature, structure, or characteristic described in connection with the indicated embodiment is included in at least one embodiment of the present solution. Thus, the phrases "in one embodiment", "in an embodiment", and similar language throughout this specification may, but do not necessarily, all refer to the same embodiment.

[0021] As used in this document, the singular form "a", "an", and "the" include plural references unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. As used in this document, the term "comprising" means "including, but not limited to".

[0022] An ideal solution to the conventional problems with RFID tags would be a device that is very small and could alert during motion while not draining any power while stationary. The device could also generate power from the motion to create a Battery Assisted Passive ("BAP") type of RFID tag from motion and/or use the motion to charge a small storage device on the tag (such as a supercap or thin film battery) to power the device while not in motion. Although RFID tags are mentioned here, this device can be used for generic Internet of Things ("IoT") devices, sensors, Central Processing Units ("CPUs"), and other circuitry or devices that want to respond to motion or use motion for energy harvesting.

[0023] The present solution provides a relatively small, inexpensive device that detects motion with no needed power and generates enough energy from motion to power an RFID tag. In this regard, motion detection sensors are provided with RFID tags. Motion detection allows the RFID tags to communicate while moving for tracking status and location. Otherwise, the RFID tags may not communicate or only communicate periodically while stationary. For passive RFID tags, there is no background RF energy needed to detect motion. BAP RFID tags for detecting motion requires constant monitoring, and therefore a drain on the small battery.

[0024] The device comprises a powerful, small permanent magnet enclosed in a thin-walled non-magnetic sphere. Disc shaped magnets and round magnets are now commercially available that are only one mm in diameter. A small plastic sphere (e.g., 3 mm in diameter) could (a) enclose the permanent magnet and (b) be wrapped with multiple turns of wire. Any motion of the sphere causes the permanent magnet to move within the sphere, thereby causing a change in magnetic flux in the wire. The change in magnetic flux causes current to be induced in the wire such that electricity is generated from the motion of the permanent magnet. Continued human or mechanical motion of the tag will cause the permanent magnet to continue to rotate and provide constant electricity on the output of the wires.

[0025] Normal motion generates at least 50 to 200 mV depending on the number of turns of the wire and the strength of the permanent magnet. This is more than enough to power an RFID tag and turn the RFID tag into a BAP type of tag with the benefits of additional range and computation power. There are standard circuits that can take this power and boost the voltage. This also provides an instant notification of motion but requires no background electricity to monitor motion circuits such as MEMS accelerometers. Motion can be used to charge and maintain an energy storage device in the RFID tag for utilization when not in motion.

[0026] Some of the novel features of the present solution are: small size and weight (e.g., 3 mm in diameter); low cost (e.g., only a few cents in medium volume); no monitoring circuitry required since motion detection is made by generating an electronic signal; and the amount of energy generated during motion is sufficient to power an RFID tag for better performance and additional circuitry. Optionally, there could be two orthogonal wraps of the wire around the non-magnetic sphere which could be tied together for energy harvesting, but could be separately analyzed to determine information about the direction and type of motion. In all scenarios, the present solution is able to generate electricity from the three dimensional ("3D") motion of the tag. This is a significant difference between conventional motion based harvesting devices which are designed to generate electricity only from two dimensional ("2D") motion of an object (e.g., a watch).

[0027] Illustrative Systems

[0028] Referring now to FIG. 1, there is provided a schematic illustration of an illustrative system **100** that is useful for understanding the present solution. The present solution is described herein in relation to a retail store environment. The present solution is not limited in this regard, and can be used in other environments. For example, the present solution can be used in distribution centers, factories and other commercial environments. Notably, the present solution can be employed in any environment in which objects and/or items need to be located and/or tracked.

[0029] The system **100** is generally configured to allow improved inventory counts of objects and/or improved inventory security within a facility. As shown in FIG. 1, system **100** comprises a Retail Store Facility ("RSF") **128** in which display equipment $\mathbf{102_1}$, . . ., $\mathbf{102_M}$ is disposed. The display equipment is provided for displaying objects (or items) $\mathbf{110_1}$-$\mathbf{110_N}$, $\mathbf{116_1}$-$\mathbf{116_X}$ to customers of the retail store. The display equipment can include, but is not limited to, shelves, article display cabinets, promotional displays, fixtures and/or equipment securing areas of the RSF **128**. The RSF can also include emergency equipment (not shown), checkout counters and an EAS system (not shown). Emergency equipment, checkout counters, and EAS systems are well known in the art, and therefore will not be described herein.

[0030] At least one tag reader **120** is provided to assist in counting the objects $\mathbf{110_1}$-$\mathbf{110_N}$, $\mathbf{116_1}$-$\mathbf{116_X}$ located within the RSF **128**. The tag reader **120** comprises an RFID reader configured to read RFID tags. RFID tags $\mathbf{112_1}$-$\mathbf{112_N}$ (collectively referred to as "**112**"), $\mathbf{118_1}$-$\mathbf{118_X}$ (collectively referred to as "**118**") are respectively attached or coupled to the objects $\mathbf{110_1}$-$\mathbf{110_N}$ (collectively referred to as "**110**"), $\mathbf{116_1}$-$\mathbf{116_X}$ (collectively referred to as "**116**"). The RFID tags are described herein as comprising single-technology tags that are only RFID enabled. The present solution is not limited in this regard. The RFID tags can alternatively or additionally comprise dual-technology tags that have both Electronic Article Surveillance ("EAS") and RFID capabilities. EAS tag technology is well known in the art, and therefore will not be described herein. Any known or to be known EAS tag technology can be used herein without limitation.

[0031] Notably, the tag reader **120** is strategically placed at a known location within the RSF **128**. By correlating the tag reader's RFID tag reads and the tag reader's known location within

the RSF **128**, it is possible to determine the location of objects **110**, **116** within the RSF **128**. The tag reader's known coverage area also facilitates object location determinations. Accordingly, RFID tag read information and tag reader location information is stored in a data store **126**. This information can be stored in the data store **126** using a server **124**. Tag readers, servers and data stores are well known in the art, and therefore will not be described herein.

[0032] Illustrative Tag Architecture

[0033] Referring now to FIG. 2, there is an illustration of an illustrative architecture for a tag **200**. RFID tags **112**, **118** are the same as or similar to tag **200**. As such, the discussion of tag **200** is sufficient for understanding the RFID tags **112**, **118** of FIG. 1. Tag **200** is generally configured to perform operations to generate electricity from the tag's motion. The manner in which the electricity is generated from the tag's motion will be discussed in detail below. The electricity is used to power various electronic components of the tag.

[0034] The tag **200** can include more or less components than that shown in FIG. 2. However, the components shown are sufficient to disclose an illustrative embodiment implementing the present solution. Some or all of the components of the tag **200** can be implemented in hardware, software and/or a combination of hardware and software. The hardware includes, but is not limited to, one or more electronic circuits. The electronic circuit(s) may comprise passive components (e.g., capacitors and resistors) and active components (e.g., processors) arranged and/or programmed to implement the methods disclosed herein.

[0035] The hardware architecture of FIG. 2 represents a representative tag **200** configured to facilitate improved inventory management. In this regard, the tag **200** is configured for allowing data to be exchanged with an external device (e.g., tag reader **120** of FIG. 1 and/or server **124** of FIG. 1) via wireless communication technology. The wireless communication technology can include, but is not limited to, a Radio Frequency Identification ("RFID") technology, a Near Field Communication ("NFC") technology, and/or a Short Range Communication ("SRC") technology. For example, one or more of the following wireless communication technologies (is)are employed: Radio Frequency ("RF") communication technology; Bluetooth technology; WiFi technology; beacon technology; and/or LiFi technology. Each of the listed wireless

communication technologies is well known in the art, and therefore will not be described in detail herein. Any known or to be known wireless communication technology or other wireless communication technology can be used herein without limitation.

[0036] The components **206-214** shown in FIG. 2 may be collectively referred to herein as a communication enabled device **204**, and include a memory **208** and a clock/timer **214**. Memory **208** may be a volatile memory and/or a non-volatile memory. For example, the memory **208** can include, but is not limited to, Random Access Memory ("RAM"), Dynamic RAM ("DRAM"), Static RAM ("SRAM"), Read Only Memory ("ROM") and flash memory. The memory **208** may also comprise unsecure memory and/or secure memory.

[0037] As shown in FIG. 2, the communication enabled device **204** comprises at least one antenna **202**, **216** for allowing data to be exchanged with the external device via a wireless communication technology (e.g., an RFID technology, an NFC technology and/or a SRC technology). The antenna **202**, **216** is configured to receive signals from the external device and/or transmit signals generated by the communication enabled device **204**. The antenna **202**, **216** can comprise a near-field or far-field antenna. The antennas include, but are not limited to, a chip antenna or a loop antenna.

[0038] The communication enabled device **204** also comprises a communications circuit **206**. Communications circuits are well known in the art, and therefore will not be described herein. Any known or to be known communications circuit can be used herein provided that it supports RFID communications. For example, in some scenarios, the communications circuit comprises a transceiver. In other scenarios, the communications circuit comprises a receiver and is configured to provide a backscatter response.

[0039] During operation, the communications circuit **206** processes received signals (e.g., RF signals) transmitted from external devices to determine whether it should transmit a response signal (e.g., RF carrier signal) to external devices or provide a backscatter response to the external device. In this way, the communication enabled device **204** facilitates the registration, identification, location and/or tracking of an item (e.g., object **110** or **112** of FIG. 1) to which the tag **200** is coupled.

[0040] In some scenarios, the communication enabled device **204** is configured so that it communicates (transmits and receives) in accordance with a motion activated communication scheme. The motion activated communication scheme involves: generating electricity from the tag's motion; and using the generated electricity to power the electronic components **206-214** of the communication enabled device **204** while the tag is in motion. Additionally, the electricity can be used to charge a storage device such as a battery or capacitor. The energy stored by the storage device can then be used to power the electronic components **206-214** of the communication enabled device **204** while the tag is stationary.

[0041] The communication enabled device **204** also facilitates the automatic and dynamic modification of item level information **226** that is being or is to be output from the tag **200** in response to certain trigger events. The trigger events can include, but are not limited to, the tag's arrival at a particular facility (e.g., RSF **128** of FIG. 1), the tag's arrival in a particular country or geographic region, a date occurrence, a time occurrence, a price change, and/or the reception of user instructions.

[0042] Item level information **226** and a unique identifier ("ID") **224** for the tag **200** can be stored in memory **208** of the communication enabled device **204** and/or communicated to other external devices (e.g., tag reader **120** of FIG. 1 and/or server **124** of FIG. 1) via communications circuit **206** and/or interface **240** (e.g., an Internet Protocol or cellular network interface). For example, the communication enabled device **204** can communicate information specifying a timestamp, a unique identifier for an item, item description, item price, a currency symbol and/or location information to an external device. The external device (e.g., server) can then store the information in a database (e.g., database **126** of FIG. 1) and/or use the information for various purposes.

[0043] The communication enabled device **204** also comprises a controller **210** (e.g., a CPU) and input/output devices **212**. The controller **210** can execute instructions **222** implementing methods for facilitating inventory counts and management. In this regard, the controller **210** includes a processor (or logic circuitry that responds to instructions) and the memory **208** includes a computer-readable storage medium on which is stored one or more sets of instructions

222 (e.g., software code) configured to implement one or more of the methodologies, procedures, or functions described herein. The instructions **222** can also reside, completely or at least partially, within the controller **210** during execution thereof by the tag **200**. The memory **208** and the controller **210** also can constitute machine-readable media. The term "machine-readable media", as used here, refers to a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions **222**. The term "machine-readable media", as used here, also refers to any medium that is capable of storing, encoding or carrying a set of instructions **222** for execution by the tag **200** and that cause the tag **200** to perform any one or more of the methodologies of the present disclosure.

[0044] The input/output devices can include, but are not limited to, a display (e.g., an E Ink display, an LCD display and/or an active matrix display), a speaker, a keypad and/or light emitting diodes. The display is used to present item level information in a textual format and/or graphical format. Similarly, the speaker may be used to output item level information in an auditory format. The speaker and/or light emitting diodes may be used to output alerts for drawing a person's attention to the tag **200** (e.g., when motion thereof has been detected) and/or for notifying the person of a particular pricing status (e.g., on sale status) of the item to which the tag is coupled.

[0045] The clock/timer **214** is configured to determine a date, a time, and/or an expiration of a pre-defined period of time. Technique for determining these listed items are well known in the art, and therefore will not be described herein. Any known or to be known technique for determining these listed items can be used herein without limitation.

[0046] The tag **200** also comprises an optional location module **230**. The location module **230** is generally configured to determine the geographic location of the tag at any given time. For example, in some scenarios, the location module **230** employs Global Positioning System ("GPS") technology and/or Internet based local time acquisition technology. The present solution is not limited to the particulars of this example. Any known or to be known technique

for determining a geographic location can be used herein without limitation including relative positioning within a facility or structure.

[0047] The optional coupler **242** is provided to securely or removably couple the tag **200** to an item (e.g., object **110** or **112** of FIG. 1). The coupler **242** includes, but is not limited to, a mechanical coupling means (e.g., a strap, clip, clamp, snap) and/or adhesive (e.g., glue or sticker). The coupler **242** is optional since the coupling can be achieved via a weld and/or chemical bond.

[0048] The tag **200** can also include an optional EAS component **244** and/or a passive/active/semi-passive RFID component **246**. Each of the listed components **244**, **246** is well known in the art, and therefore will not be described herein. Any known or to be known battery, EAS component and/or RFID component can be used herein without limitation.

[0049] As shown in FIG. 2, the tag **200** further comprises an energy harvesting circuit **232**. In some scenarios, the energy harvesting circuit **232** is configured to harvest energy from the tag's motion and to generate output power from the harvested energy. The energy harvesting circuits will be discussed below in relation to FIGS. 3-6.

[0050] As noted above, the tag **200** may also include one or more sensors **250**. Sensors are well known in the art, and therefore will not be described herein. Any known or to be known sensor can be used herein without limitation. For example, the sensor **250** includes, but is not limited to, a vibration sensor, an accelerometer, a gyroscope, a linear motion sensor, a Passive Infrared ("PIR") sensor, a tilt sensor, a rotation sensor, a temperature sensor, and/or a proximity sensor.

[0051] The present solution is not limited to that shown in FIG. 2. The tag **200** can have any architecture provided that it can perform the functions and operations described herein. For example, all of the components shown in FIG. 2 can comprise a single device (e.g., an Integrated Circuit ("IC")). Alternatively, some of the components can comprise a first tag element (e.g., a Commercial Off The Shelf ("COTS") tag) while the remaining components comprise a second tag element communicatively coupled to the first tag element. The second

tag element can provide auxiliary functions (e.g., motion sensing, etc.) to the first tag element. The second tag element may also control operational states of the first tag element. For example, the second tag element can selectively (a) enable and disable one or more features/operations of the first tag element (e.g., receiver operations), (b) couple or decouple an antenna to and from the first tag element, and/or (c) cause an operational state of the first tag element to be changed (e.g., cause transitioning the first tag element between a power save mode and non-power save mode).

[0052] Referring now to FIG. 3, there is provided a block diagram of an illustrative architecture for the energy harvesting circuit **300**. The energy harvesting circuit **232** of FIG. 2 can be the same as energy harvesting circuit **300**. As such, the discussion of energy harvesting circuit **300** is sufficient for understanding the energy harvesting circuit **232** of FIG. 2. The energy harvesting circuit **300** is not limited to the particular architecture shown in FIG. 3. In this regard, it should be understood that the energy harvesting circuit **300** can include more or less components than that shown in FIG. 3. An illustrative energy harvesting circuit including more components than that of FIG. 3 is provided in FIG. 4, which will discussed below.

[0053] The energy harvesting circuit **300** is configured to provide a way in which a tag (e.g., tag **200**) is a self-sustaining sensor system wherein its power source would virtually never need to be replaced. In this regard, the energy harvesting circuit **300** comprises a motion based electricity generator **302**, a Super Capacitor ("SC") storage element **304**, and a voltage converter **308** electrically connected to a load(s) **310**. The load **310** can include, but is not limited to, components **204**, **230**, **240**, **250**, **244** and/or **246** of FIG. 2.

[0054] At initial power up of the tag, the SC storage element **304** is assumed to be in a completely discharged state. Thus, the initial charge of the SC storage element **304** is at a level of approximately or substantially equal to zero volts. However, electricity is generated by the motion based electricity generator **302** when the tag is in motion. This generated electricity is used to charge the SC storage element **304**. An output voltage **306** of the SC storage element is supplied to the load(s) **310** via the voltage converter **308**. The tag **200** is considered fully operational when the output voltage **306** reaches a level (e.g., 3.8 V) that is sufficient to cause

the load(s) to perform the intended operations thereof.

[0055] Referring now to FIG. 4, there is provided a block diagram of another illustrative architecture for an energy harvesting circuit **400** of a tag (e.g., tag **200** of FIG. 2). The energy harvesting circuit **232** of FIG. 2 can be the same as energy harvesting circuit **400**. As such, the discussion of energy harvesting circuit **400** is sufficient for understanding the energy harvesting circuit **232** of FIG. 2. The energy harvesting circuit **400** is not limited to the particular architecture shown in FIG. 4. In this regard, it should be understood that the energy harvesting circuit **400** can include more or less components than that shown in FIG. 4.

[0056] The energy harvesting circuit **400** is configured to provide a way in which the tag is a self-sustaining sensor system wherein its power source would virtually never need to be replaced. In this regard, the energy harvesting circuit **400** comprises a motion based electricity generator **402**, switches **404**, **406**, an Energy Harvester Power Manager ("EHPM") **408**, a rechargeable battery **436**, an SC storage element **414**, a smart charger **412** for the SC storage element, a microcontroller **416**, and a DC-DC voltage converter **420** electrically connected to a load(s) **422**. The microcontroller **416** can be the same as or separate/distinct from the controller **210** of FIG. 2. The load **422** can include, but is not limited to, components **204**, **230**, **240**, **250**, **244** and/or **246** of FIG. 2.

[0057] At initial power up of the tag **200**, the SC storage element **414** is assumed to be in a completely discharged state. Thus, the initial charge of the SC storage element **414** is at a level of approximately or substantially equal to zero volts. However, the power source (e.g., rechargeable battery) **436** is in a quasi-discharged state in which its initial charge is at a level greater than zero volts (e.g., 3 volts). As such, the power source (e.g., rechargeable battery) **436** has a sufficient amount of initial stored energy to nearly instantaneously enable operations of the control electronics of the tag. In this regard, an output voltage **436** is supplied from the power source (e.g., rechargeable battery) **436** to the EHPM **408** via switch **404**, whereby operations of the EHPM **408** are started immediately after turning on the tag. The output voltage **436** is also supplied from the power source (e.g., rechargeable battery) **436** to the microcontroller **416** via the EHPM **408**.

[0058] The available power from power source (e.g., rechargeable battery) is also used at this time to charge the SC storage element **414**. In this regard, the output voltage **436** of the power source (e.g., rechargeable battery) **436** is supplied to the SC storage element **414** via switch **406** and smart charger **412**, whereby charging of the SC storage element is expedited. An output voltage **438** of the SC storage element is supplied to the load(s) **422** via the voltage converter **420**. The tag is considered fully operational when the output voltage **438** reaches a level (e.g., 3.8 V) that is sufficient to cause the load(s) to perform the intended operations thereof.

[0059] Throughout operation of the tag **400**, the microcontroller **416** monitors the output voltage **434** of the motion based electricity generator **402**, as well as the output voltage **436** of the power source (e.g., rechargeable battery) and the output voltage **438** of the SC storage element **414**. Once the output voltage **438** of the SC storage element **414** reaches a desired voltage (e.g., 3.8 V) after system activation (or powering on), the microcontroller **416** enables a timer to time the charging of the SC storage element **414**. After a pre-determined time period, an assumption is made that the SC storage element **414** has reached its leakage current equilibrium, and therefore no longer needs to be charged. In effect, the microcontroller **416** may optionally perform operations at this time to terminate the supply of output voltage **436** to the SC storage element **414** via switch **406** and smart charger **412**.

[0060] When the output voltage **438** of the SC storage element **414** falls below a threshold value (e.g., 3.3 V), the microcontroller **416** communicates a switch control signal **432** to switch **406** so as cause the output voltage **436** of the power source (e.g., rechargeable battery) **410** to once again be supplied to the SC storage element **414** via the smart charger **412**. Output voltage **436** is supplied to the SC storage element **414** until the output voltage **438** thereof exceeds an upper threshold value. In effect, the SC storage element **414** is recharged whereby the energy expended while driving load(s) **422** is(are) restored.

[0061] When the motion based electricity generator **402** is active, the output voltage **434** of the motion based electricity generator **402** is supplied to the power source (e.g., rechargeable battery) **336** via EHPM **408**. In effect, the power source (e.g., rechargeable battery) **336** is recharged by the motion based electricity generator **402**, whereby the energy expended in

charging and re-charging the SC storage element **414** is restored while the tag **400** is maintained in its fully operational state.

[0062] The above described process of using the power source (e.g., rechargeable battery) **336** to charge the SC storage element **414** is repeated as needed. Thus, the above described tag **400** performs self-monitoring and charges its respective re-chargeable elements throughout its entire operation.

[0063] Referring now to FIGS. 5-6, there are provided illustrations that are useful for understanding a motion based electricity generator **600**. Motion based electricity generators **302**, **402** are the same as or substantially similar to motion based electricity generator **600**. As such, the discussion of motion based electricity generator **600** is sufficient for understanding motion based electricity generators **302**, **402**.

[0064] The motion based electricity generator **600** employs a device able to convert motion of the tag into electricity. This device comprises a hollow sphere **502** in which a spherical permanent magnet **504** is disposed. The hollow sphere **502** is formed of any non-magnetic material. Such non-magnetic materials, include but are not limited to, plastic, aluminum, glass and/or wood. The spherical permanent magnet **504** is disposed inside the hollow sphere **502** such that it can move freely therein, as shown by arrows **506**, **508**. Any motion of the hollow sphere **502** is easily detected as the spherical permanent magnet **504** rolls therein. Continuous walking motion causes the spherical permanent magnet **504** to rotate and bounce around within the hollow sphere **502**.

[0065] The movement of the spherical permanent magnet **504** can be used to generate electricity. In this case, a wire **602** is wrapped around the hollow sphere **502**, as shown in FIG. 6. Motion and rotation of the spherical permanent magnet **504** causes a change in a magnetic flux in the wire **602**. This change in magnetic flux causes a current to be induced in the wire **602**.

[0066] Although the wire **602** is shown in FIG. 6 as extending in a single direction along the surface of the hollow sphere, the present solution is not limited in this regard. For example, in

some scenarios, the wire is disposed on the hollow sphere such that there are at least two orthogonal wraps thereof around the hollow sphere. This orthogonal wire configuration ensures that motion and rotation of the spherical permanent magnet **504** in any direction will produce energy.

[0067] An illustration of a motion based electricity generator **700** having such an orthogonal wire configuration is shown in FIG. 7. Motion based electricity generators **302**, **402** are the same as or substantially similar to motion based electricity generator **700**. As such, the discussion of motion based electricity generator **700** is sufficient for understanding motion based electricity generators **302**, **402**.

[0068] The motion based electricity generator **700** employs a device able to convert motion of the tag into electricity. This device comprises a hollow sphere **704** in which a spherical permanent magnet **706** is disposed. The hollow sphere **704** is formed of any non-magnetic material. Such non-magnetic materials, include but are not limited to, plastic, aluminum, glass and/or wood. The spherical permanent magnet **706** is disposed inside the hollow sphere **704** such that it can move freely therein. Any motion of the hollow sphere **704** is easily detected as the spherical permanent magnet **706** rolls therein. Continuous walking motion causes the spherical permanent magnet **706** to rotate and bounce around within the hollow sphere **704**.

[0069] The movement of the spherical permanent magnet **706** can be used to generate electricity. In this case, a wire **702** is wrapped around the hollow sphere **704**, as shown in FIG. 7. Motion and rotation of the spherical permanent magnet **706** causes a change in a magnetic flux in the wire **702**. This change in magnetic flux causes a current to be induced in the wire **702**.

[0070] The AC output voltage of the wire **702** is converted into a DC voltage via a diode bridge **710**. Diode bridges are well known in the art, and therefore will not be described herein. Still, it should be understood that the diode bridge **710** is a full wave rectifier that is able to harvest energy in both directions. Notably, low current in this design can utilize lower than standard diode breakdown voltages. The DC output voltage of the diode bridge **710** is optionally provided to a voltage booster **508**. Voltage boosters are well known in the art, and therefore will

not be described herein. Any known or to be known voltage booster can be used herein without limitation.

[0071] Referring now to FIG. 8, there is provided a flow diagram of an illustrative method **800** for operating a tag (e.g., tag **112**, **118** of FIG. 1 or **200** of FIG. 2). Method **800** begins with **802** and continues with **804** where motion of a spherical permanent magnet (e.g., spherical permanent magnet **504** of FIG. 5 or **706** of FIG. 7) is caused. The spherical permanent magnet is disposed and freely movable in a three dimensional internal space (e.g., space **506** of FIG. 5) of a non-magnetic hollow sphere (e.g., hollow sphere **502** of FIG. 5) located within the tag.

[0072] In **806**, the spherical permanent magnet's motion is used to cause a change in a magnetic flux in a wire (e.g., wire **602** of FIG. 6 or **702** of FIG. 7) wrapped around at least a portion of the non-magnetic hollow sphere. The wire extends in a single direction along an outer surface of the non-magnetic hollow sphere, or is wrapped around the non-magnetic hollow sphere in at least two orthogonal directions. The change in the magnetic flux induces a current in the wire. The current is generated from 3D motion of the spherical permanent magnet. The current is used in **808** to supply power to at least one device of the tag's internal electronic devices that is configured to facilitate at least one of an inventory count and an inventory security. The device includes, but is not limited to, a communications enabled device (e.g., communications enabled device **204** of FIG. 2) and/or an energy storage device (e.g., a rechargeable battery **436** of FIG. 4, a super capacitor storage element **304** of FIG. 3, and/or a super capacitor storage element **414** of FIG. 4). In some scenarios, the communications enabled device is supplied power only when the tag is in motion or the tag's magnetic current has indicated or is indicating that the tag is in motion. A value of the tag's magnetic current can be compared to a threshold value to determine if it indicates that the tag is in motion or has been in motion within a certain period of time (e.g., within the last 1-5 seconds). Subsequently, **810** is performed where method **800** ends or other operations are performed (e.g., communicate information (e.g., items **224** and/or **226** of FIG. 2) from the tag to an external device (e.g., tag reader **120** of FIG. 1).

[0073] Although the present solution has been illustrated and described with respect to one or more implementations, equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In addition, while a particular feature of the present solution may have been disclosed with respect to only one of several implementations, such feature may be combined with one or more other features of the other implementations as may be desired and advantageous for any given or particular application. Thus, the breadth and scope of the present solution should not be limited by any of the above described embodiments. Rather, the scope of the present solution should be defined in accordance with the following claims and their equivalents.

CLAIMS

What is claimed is:

1. A method for operating a tag, comprising:

causing motion of a spherical permanent magnet which is disposed and freely movable in a three dimensional internal space of a non-magnetic hollow sphere located within the tag;

using the spherical permanent magnet's motion to cause a change in a magnetic flux in a wire wrapped around at least a portion of the non-magnetic hollow sphere, where the change in the magnetic flux induces a current in the wire; and

using the current to supply power to at least one device of the tag's internal electronic devices that is configured to facilitate at least one of an inventory count and an inventory security.

2. The method according to claim 1, wherein the wire extends in a single direction along an outer surface of the non-magnetic hollow sphere.

3. The method according to claim 1, wherein the wire is wrapped around the non-magnetic hollow sphere in at least two orthogonal directions.

4. The method according to claim 1, wherein the tag is a Radio Frequency Identification ("RFID") tag.

5. The method according to claim 1, wherein the current is generated from 3D motion of the spherical permanent magnet.

6. The method according to claim 1, wherein the at least one device comprises a communications enabled device.

7. The method according to claim 1, wherein the communications enabled device is supplied power only when the tag's magnetic current has indicated that the tag is in motion.

8. The method according to claim 1, wherein the at least one device comprises an energy storage device.

9. The method according to claim 1, wherein the energy storage device comprises a rechargeable battery or a capacitor.

10. The method according to claim 1, wherein the tag comprises an Electronic Article Surveillance component.

11. A tag, comprising:

an electricity generator comprising a spherical permanent magnet which is disposed and freely movable in a three dimensional internal space of a non-magnetic hollow sphere, where the spherical permanent magnet's motion causes a change in a magnetic flux in a wire wrapped around at least a portion of the non-magnetic hollow sphere, the change in the magnetic flux inducing a current in the wire; and

an electronic device which is powered using the current and that is configured to facilitate at least one of an inventory count and an inventory security.

12. The tag according to claim 11, wherein the wire extends in a single direction along an outer surface of the non-magnetic hollow sphere.

13. The tag according to claim 11, wherein the wire is wrapped around the non-magnetic hollow sphere in at least two orthogonal directions.

14. The tag according to claim 11, wherein the tag is a Radio Frequency Identification ("RFID") tag.

15. The tag according to claim 11, wherein the current is generated from 3D motion of the spherical permanent magnet.

16. The tag according to claim 11, wherein the electronic device comprises a communications enabled device.

17. The tag according to claim 11, wherein the communications enabled device is supplied power only when the tag's magnetic current has indicated that the tag is in motion.

18. The tag according to claim 11, wherein the electronic device comprises an energy storage device.

19. The tag according to claim 11, wherein the energy storage device comprises a rechargeable battery or a capacitor.

20. The tag according to claim 11, wherein the tag comprises an Electronic Article Surveillance component.

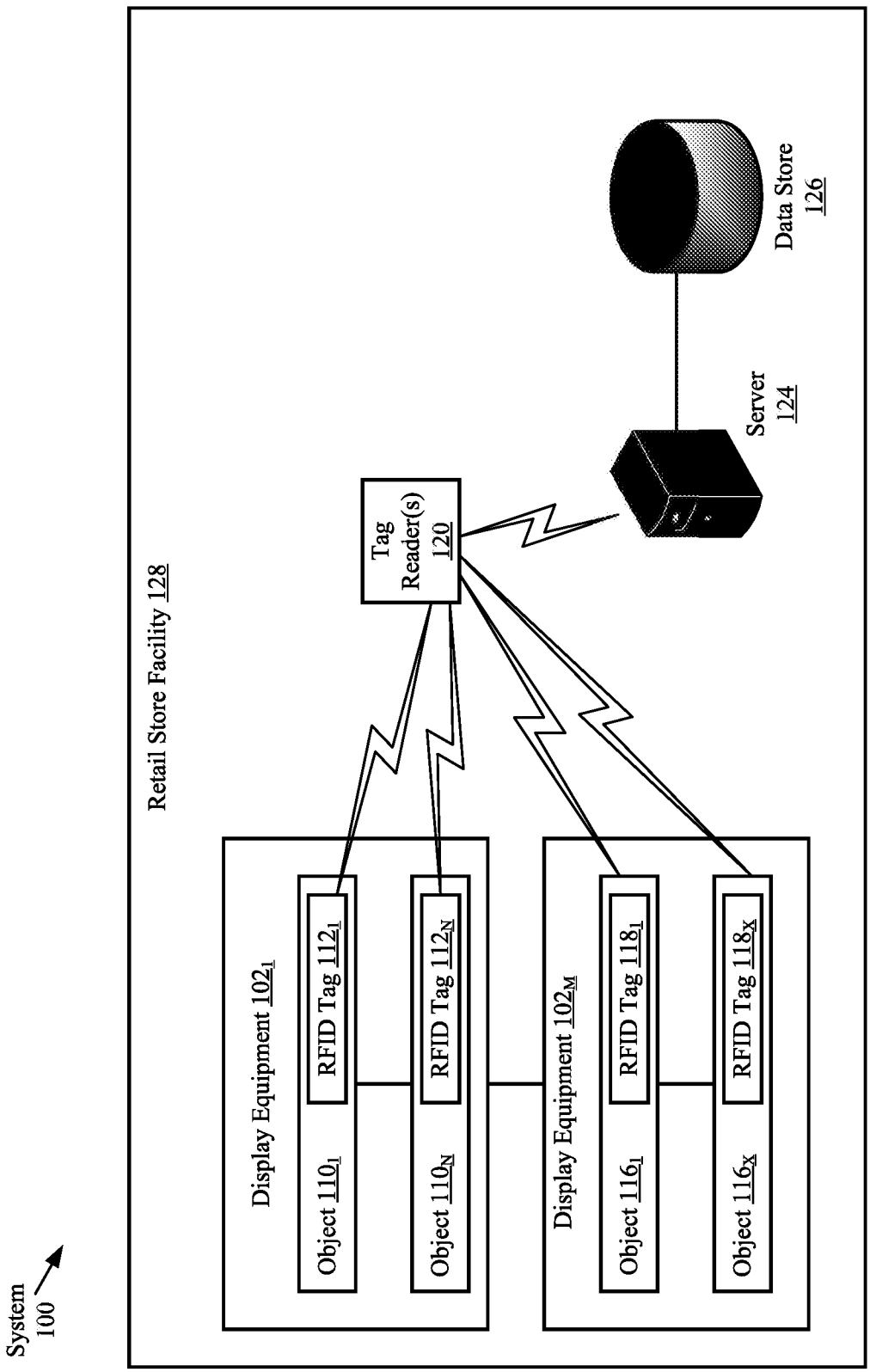
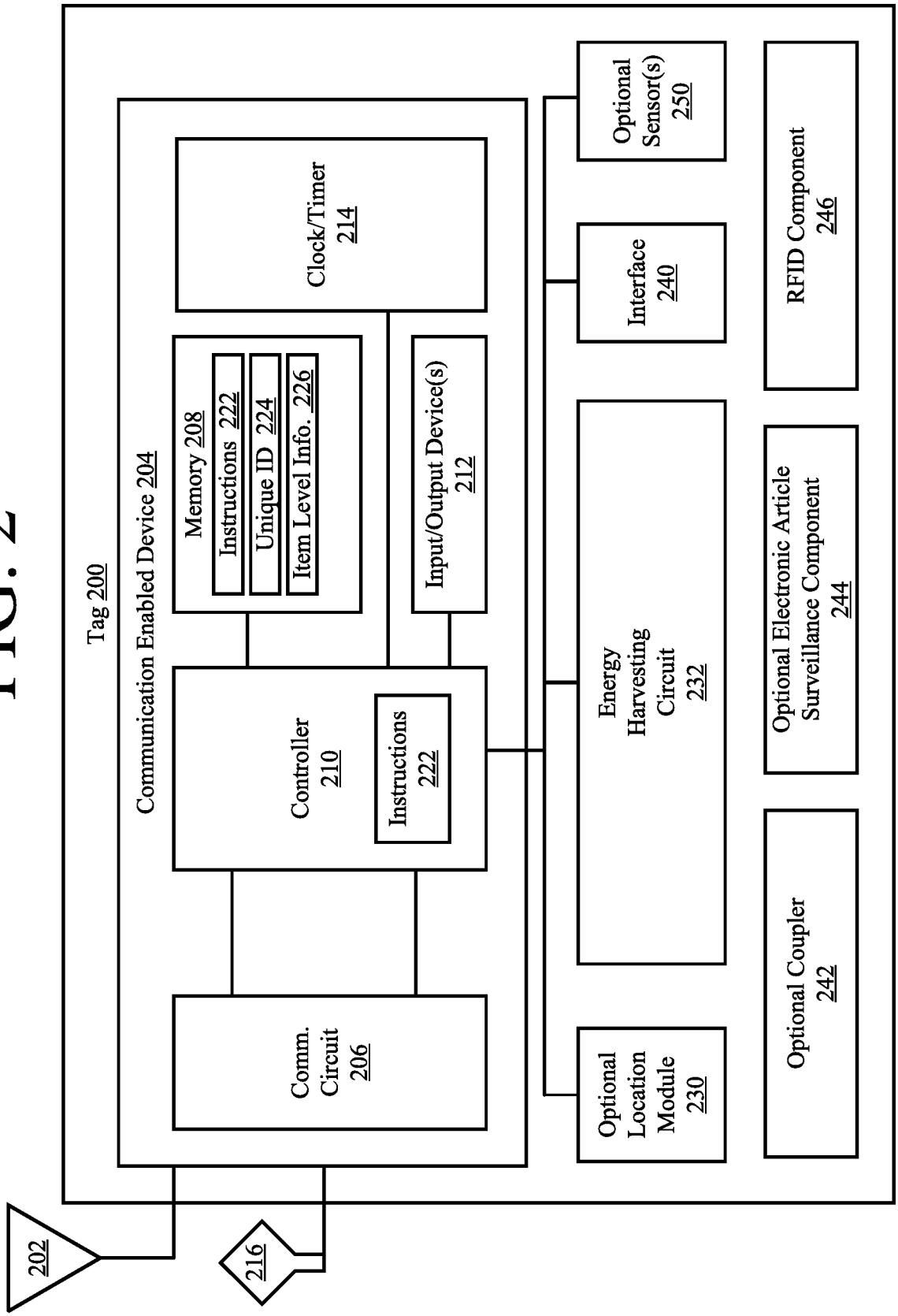

System
100
Retail Store Facility 128
Display Equipment 102$_1$
Object 110$_1$
RFID Tag 112$_1$
Object 110$_N$
RFID Tag 112$_N$
Display Equipment 102$_M$
Object 116$_1$
RFID Tag 118$_1$
Object 116$_X$
RFID Tag 118$_X$
Tag Reader(s) 120
Server 124
Data Store 126

FIG. 1

FIG. 2


Tag 200
Communication Enabled Device 204
Memory 208
Instructions 222
Unique ID 224
Item Level Info. 226
Clock/Timer 214
Controller 210
Instructions 222
Input/Output Device(s) 212
Comm. Circuit 206
Optional Location Module 230
Energy Harvesting Circuit 232
Interface 240
Optional Sensor(s) 250
Optional Coupler 242
Optional Electronic Article Surveillance Component 244
RFID Component 246
202
216

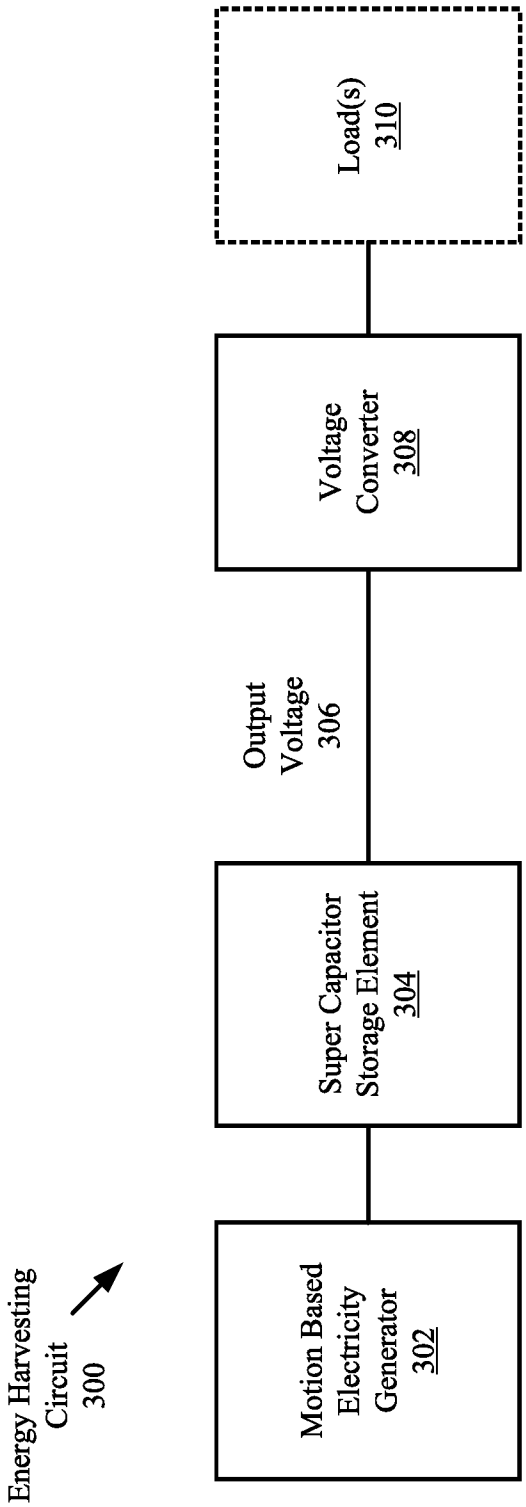

Energy Harvesting Circuit 300
Motion Based Electricity Generator 302
Super Capacitor Storage Element 304
Output Voltage 306
Voltage Converter 308
Load(s) 310

FIG. 3

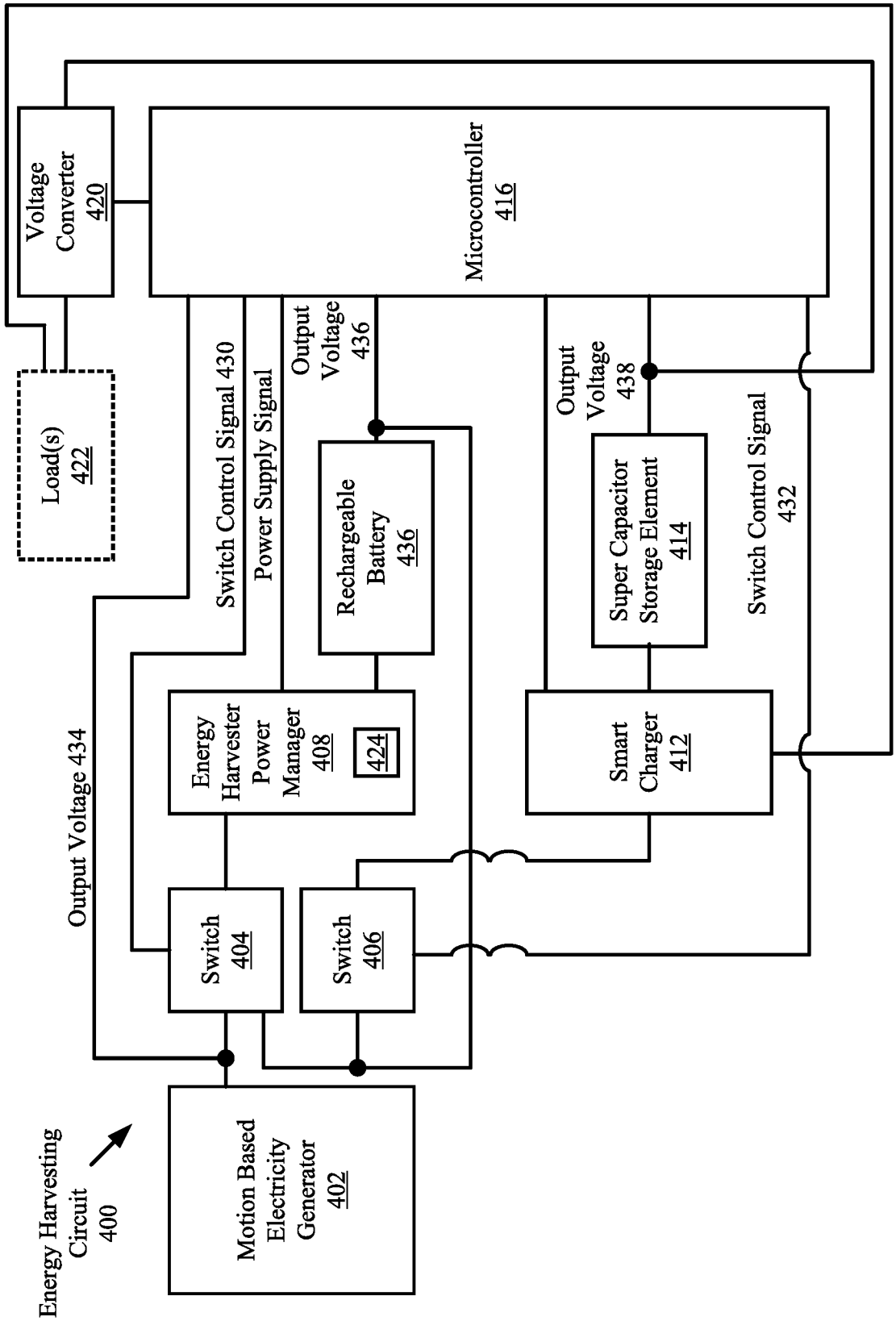

Energy Harvesting Circuit 400
Motion Based Electricity Generator 402
Switch 404
Switch 406
Energy Harvester Power Manager 408
424
Smart Charger 412
Output Voltage 434
Switch Control Signal 430
Power Supply Signal
Output Voltage 436
Rechargeable Battery 436
Output Voltage 438
Super Capacitor Storage Element 414
Switch Control Signal 432
Microcontroller 416
Voltage Converter 420
Load(s) 422

FIG. 4

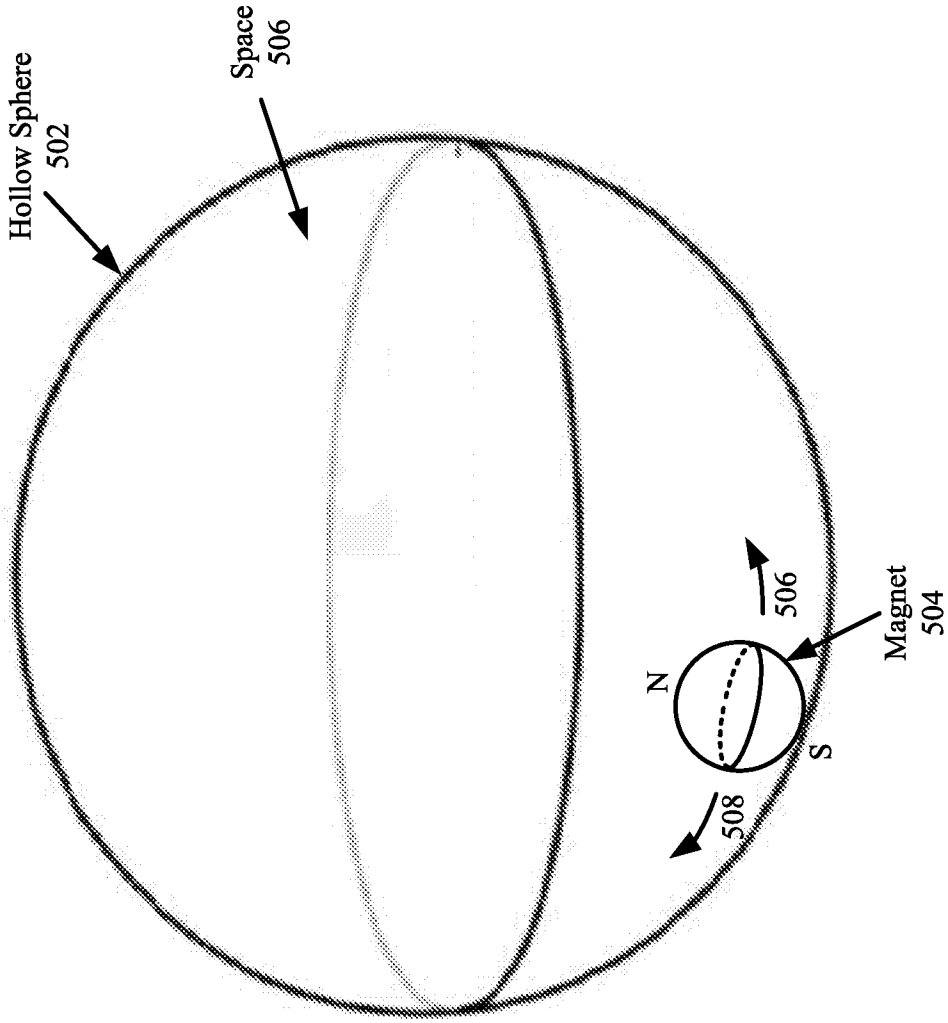


FIG. 5

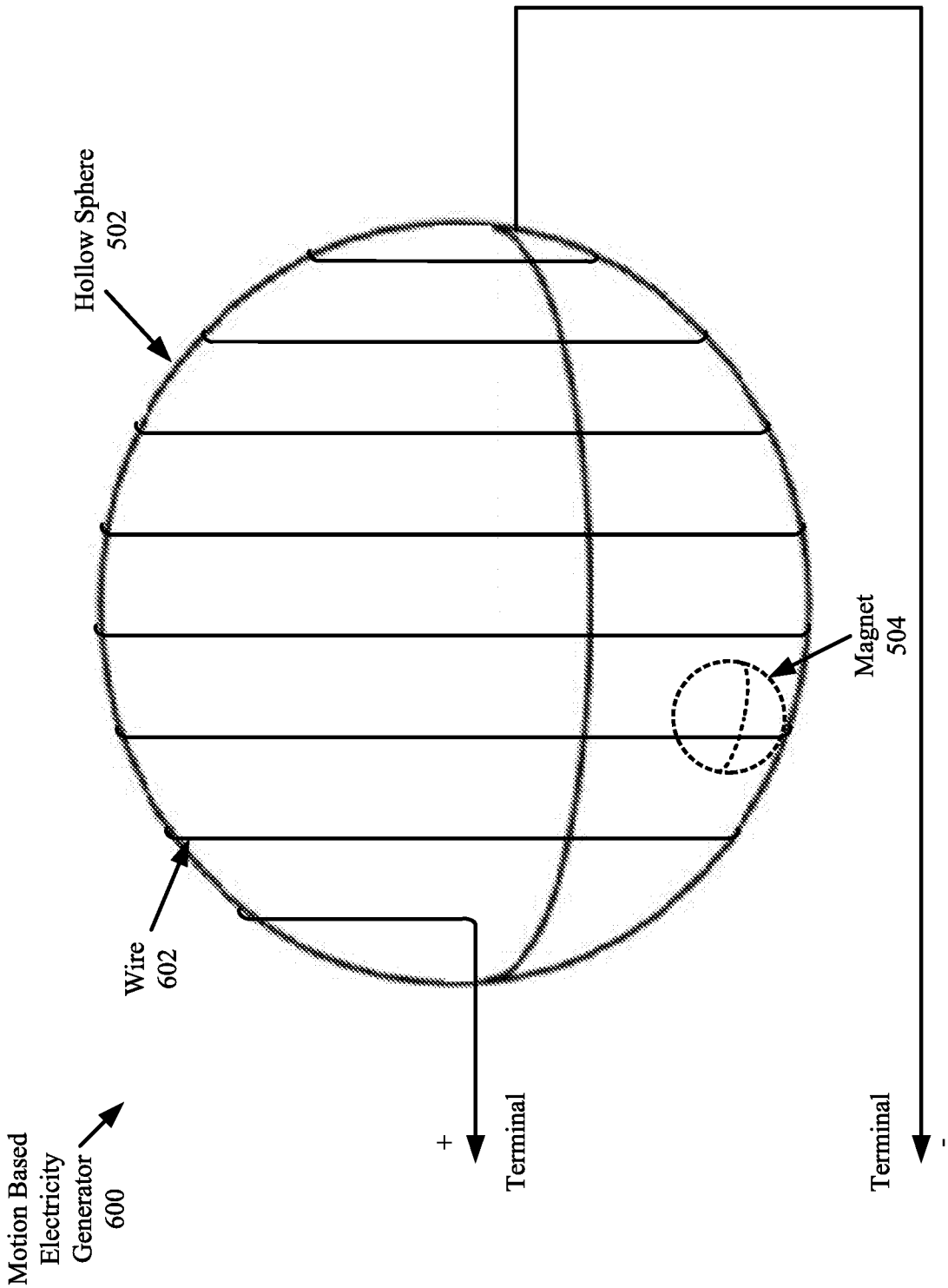

Motion Based Electricity Generator 600
Hollow Sphere 502
Wire 602
Magnet 504
+ Terminal
- Terminal

FIG. 6

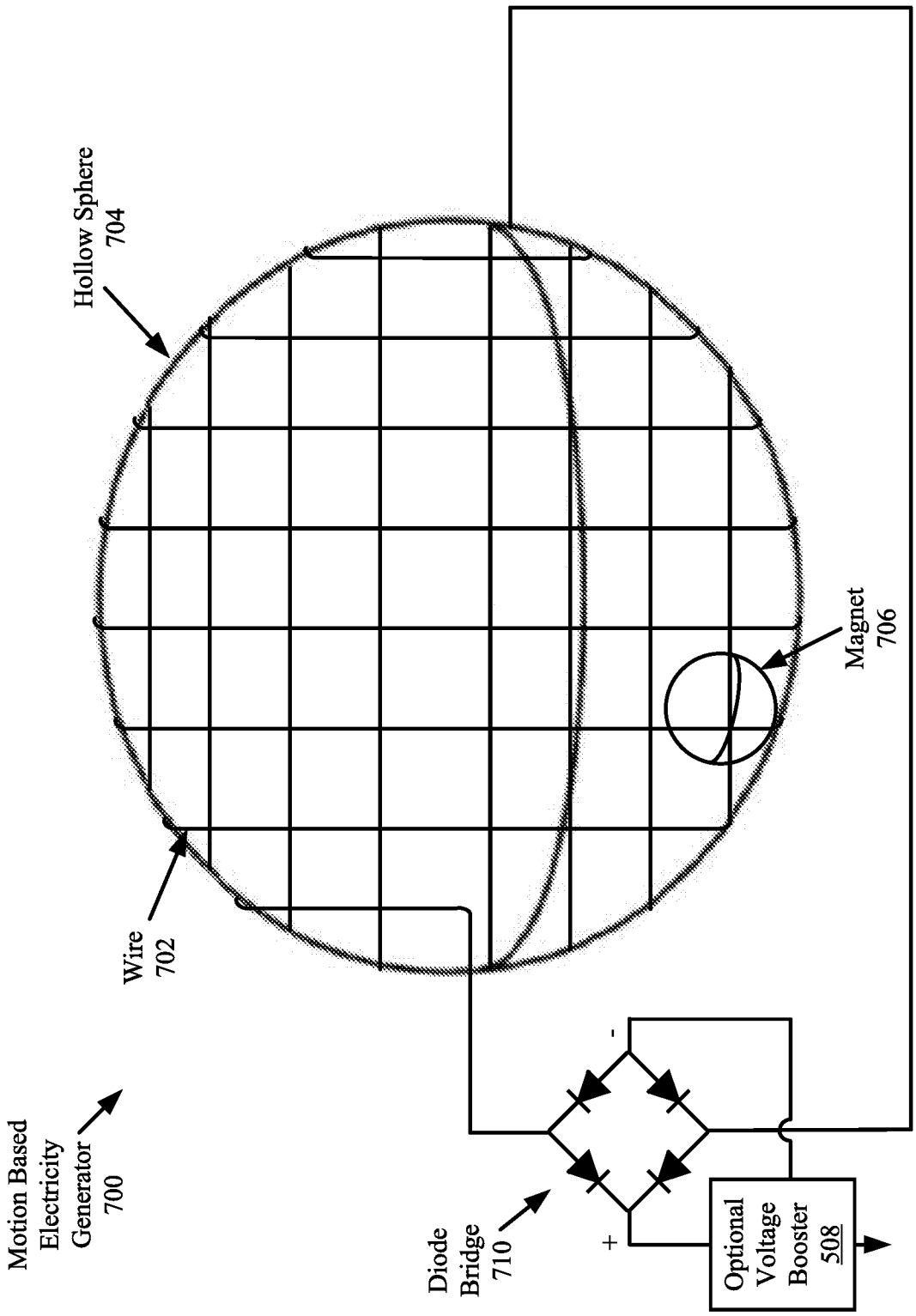

Motion Based Electricity Generator 700
Hollow Sphere 704
Wire 702
Magnet 706
Diode Bridge 710
-
+
Optional Voltage Booster 508

FIG. 7

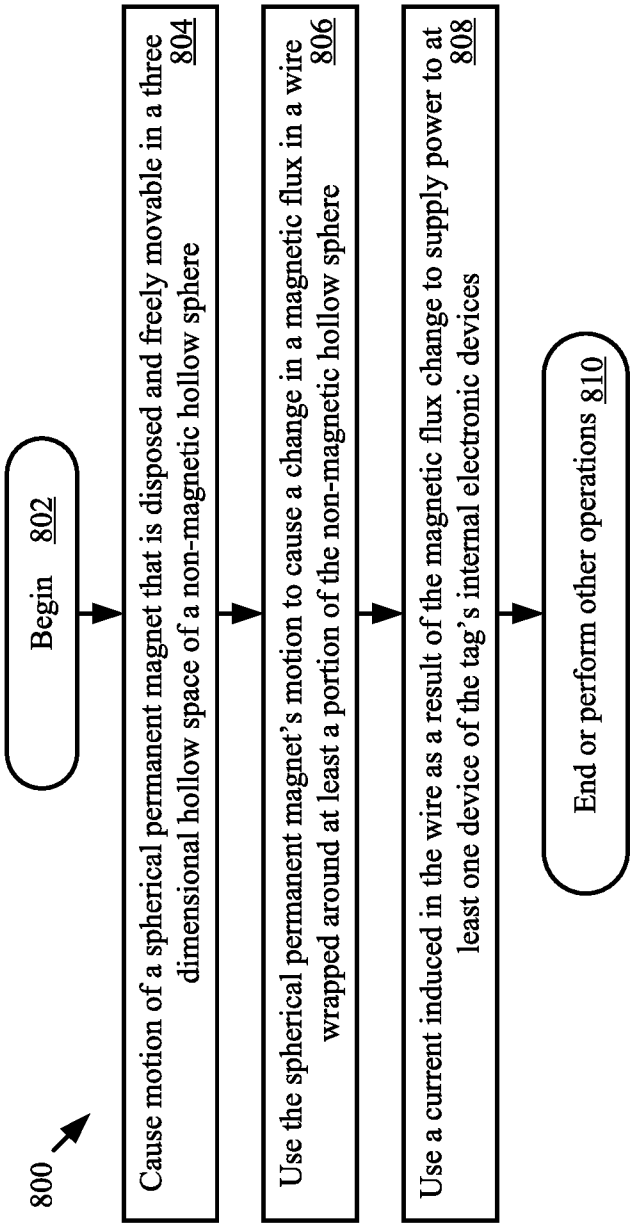

800
Begin 802
Cause motion of a spherical permanent magnet that is disposed and freely movable in a three dimensional hollow space of a non-magnetic hollow sphere 804
Use the spherical permanent magnet's motion to cause a change in a magnetic flux in a wire wrapped around at least a portion of the non-magnetic hollow sphere 806
Use a current induced in the wire as a result of the magnetic flux change to supply power to at least one device of the tag's internal electronic devices 808
End or perform other operations 810

FIG. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/029589

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06K19/07
ADD.

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)
G06K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2018/040219 A1 (CLARK JOHN J [US] ET AL) 8 February 2018 (2018-02-08) paragraph [0036] - paragraph [0051] figures 3A, 3B	1-20
Y	US 2011/187207 A1 (ARNOLD DAVID P [US] ET AL) 4 August 2011 (2011-08-04) paragraph [0002] paragraph [0050] - paragraph [0057] paragraphs [0069], [0070]; figures 11 - 13	1-20
Y	US 2017/187253 A1 (MOYERMAN STEPHANIE [US] ET AL) 29 June 2017 (2017-06-29) paragraph [0008] - paragraph [0017]	1,4-11, 14-20
A	US 2012/032803 A1 (COPELAND RICHARD L [US] ET AL) 9 February 2012 (2012-02-09) the whole document	1-20

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

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 July 2019	19/07/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Geiger, Hans-Walter

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2019/029589

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