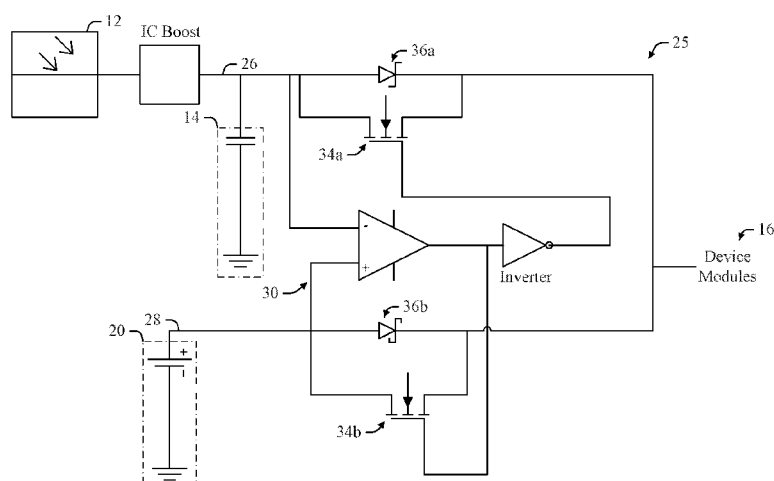




- (51) **International Patent Classification:**
H02J 7/00 (2006.01) **H04L 12/28** (2006.01)
H02J 7/34 (2006.01)
- (21) **International Application Number:**
PCT/US2016/060620
- (22) **International Filing Date:**
4 November 2016 (04.11.2016)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
14/969,925 15 December 2015 (15.12.2015) US
- (63) **Related by continuation (CON) or continuation-in-part (CIP) to earlier application:**
US 14/969,925 (CON)
Filed on 15 December 2015 (15.12.2015)
- (71) **Applicant: INTEL CORPORATION** [US/US]; 2200 Mission College Boulevard, Santa Clara, California 95052 (US).
- (72) **Inventors: NI SCANAILL, Clíodhna;** Cadamstown, Broadford (IE). **KELLY, Mark;** Collinstown Industrial Estate Leixlip, Leixlip (IE). **NOLAN, Keith;** 202 Ashfield, Mullingar, 0000 (IE). **LAZARUT, Aurelian;** 141 Branswood, Kilkenny Road, Athy (IE).
- (74) **Agents: WOO, Justin N.** et al.; Schwegman, Lundberg & Woessner, P.A., CPA Global, 900 Second Avenue South, Suite 600, Minneapolis, Minnesota 55402 (US).
- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).
- Published:**
— with international search report (Art. 21(3))

(54) **Title:** ENERGY HARVESTING SYSTEM FOR IOT DEVICES**FIG. 2A**

(57) **Abstract:** A system and related methods for powering a device module of IoT device with an energy harvesting module. A supercapacitor is charged by the energy harvesting module and discharged to the device module to power the device module. The discharge from the supercapacitor may be scheduled to power demanding tasks to provide sufficient recharging periods for the supercapacitor and avoid discharging the supercapacitor when the supercapacitor is insufficiently charged.

ENERGY HARVESTING SYSTEM FOR IOT DEVICES

5

PRIORITY APPLICATION

[0001] This application claims the benefit of priority to U.S. Application Serial No. 14/969,925, filed December 15, 2015, which is incorporated herein by reference in its entirety.

10

TECHNICAL FIELD

[0002] This document pertains generally, but not by way of limitation, to energy harvesting systems and related methods for powering Internet of Things ("IoT") devices.

15

BACKGROUND

[0003] Many IoT devices can be configured for monitoring or other functions in remote geographic locations or other locations where the IoT device cannot be powered by a power grid. These IoT devices can be powered by self-contained power sources that typically include batteries for powering the sensors, transmitters, receivers, and other device modules of the IoT device. Recently, energy harvesters, such as solar panels and wind turbines, have been integrated into IoT devices to continually recharge the batteries of the IoT device if the batteries are depleted from powering the device modules. While the energy harvesters permit recharging of discharged batteries, the rechargeable batteries still require regular maintenance and replacement hampering the effectiveness of the IoT device. The continual and repeated recharging of the chemical batteries gradually reduces the effective charge that can be received by the batteries and eventually require that no longer effective batteries to be replaced. In addition, certain IoT devices regularly perform tasks requiring substantial power discharges, such as long range and substantial data or message transmissions, which further reduces the effectiveness of the batteries over time.

[0004] As the ineffective batteries must often be replaced within the overall life of the IoT device, the IoT device is constructed with an access panel or other doorway to permit access to the batteries. However, the access point can also permit moisture and other contaminants to penetrate the interior of the IoT

device and damage the device. As these types of IoT devices are often placed in locations with harsh and/or turbulent weather for providing monitoring of those locations, the IoT devices are often subjected to inclement weather and other situations, such as flooding, which could exploit the battery replacement access panel and cause moisture or containments to penetrate the IoT device.

[0005] Similarly, chemical batteries are vulnerable to reduced effectiveness when subjected to extreme cold or warm temperatures and/or at high altitudes. As such, insulation or other special precautions to prevent reduced effectiveness or failure of the IoT device due to insufficient power provided by the batteries. The added precautions increase the expense and complexity of the IoT device. In addition, heating or cooling systems will further drain the battery and reduce the overall effectiveness of the IoT device.

[0006] As such, powering the IoT device with the battery significantly hinders the longevity of the IoT device and increases the maintenance required by the IoT device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] In the drawings, which are not necessarily drawn to scale, like numerals may describe similar components in different views. Like numerals having different letter suffixes may represent different instances of similar components. The drawings illustrate generally, by way of example, but not by way of limitation, various embodiments discussed in the present document.

[0008] Figure 1A is a schematic diagram of an IoT device according to an example of the present disclosure in which an energy harvesting module is integral to the IoT device.

[0009] Figure 1B is a schematic diagram of an IoT device according to an example of the present disclosure having a supercapacitor rechargeable by an energy harvesting module and a non-rechargeable secondary battery.

[0010] Figure 1C is a schematic diagram of an IoT device according to an example of the present disclosure in which an energy harvesting module is remote from a supercapacitor of the IoT device.

[0011] Figure 1D is a schematic diagram of an IoT device according to an example of the present disclosure having two energy harvesting modules configured to convert energy from different energy sources.

[0012] Figure 2A is circuit diagram of a hybrid power circuit according to an example of the present disclosure.

[0013] Figure 2B is a circuit diagram of the hybrid power circuit depicted in FIG. 2A, wherein power is being discharged from the supercapacitor when the supercapacitor has a higher voltage than the battery.

[0014] Figure 2C is a circuit diagram of the hybrid power circuit depicted in FIG. 2A, wherein power is being discharged from the secondary battery.

[0015] Figure 3 is a voltage profile of a supercapacitor and a battery according to an example of the present disclosure, wherein an energy harvesting device is continually recharging the supercapacitor.

[0016] Figure 4 is a voltage profile of a supercapacitor and a battery according to an example of the present disclosure, wherein recharging the supercapacitor by an energy harvesting device is halted and the battery is supplementing the supercapacitor.

[0017] Figure 5 is a schematic diagram of a process for scheduling tasks according to available energy according to an example of the present disclosure.

[0018] Figure 6 is a schematic diagram of a process for determining whether maintenance of an IoT device is required according to an example of the present disclosure.

[0019] Figure 7 is a schematic diagram illustrating an example controller module for running any one or more of the methodologies discussed herein.

DESCRIPTION OF EMBODIMENTS

[0020] The present inventors have recognized, among other things, that a problem to be solved can include the increased maintenance and gradually reducing effectiveness of IoT devices resulting from the use of batteries as the primary or sole power source for IoT devices. In an example, the present subject matter can provide a solution to this problem, such as by providing an IoT device that may have a supercapacitor powering a device module and an energy harvesting module for recharging the supercapacitor. As the device module is powered by the discharge of the supercapacitor, the IoT device may be energy source agnostic and the energy harvesting module may be selected according to the most readily available energy source.

[0021] The energy harvesting module may continuously charge or regularly recharge the supercapacitor without gradually reducing charge capacity as with conventional chemical batteries. Similarly, the supercapacitor may be repeatedly fully discharged without impacting the overall charge capacity of the supercapacitor. In addition, the supercapacitor is less susceptible to reduced performance or damage from extreme temperatures than chemical batteries. As such, regular replacement of the battery may be avoided thereby permitting a more complete sealing of the IoT device against moisture and contaminants.

[0022] In an example, the IoT device may be configured to evaluate energy consumption of the device module during an initial training period. During the initial training period, a controller may evaluate energy demanding tasks for the device module and power harvesting by the power harvesting module. The controller may alter the queue of tasks to schedule the tasks to align with power harvesting windows such that the supercapacitor is continually recharged by the power harvesting module as the supercapacitor is discharged. This configuration may also schedule the energy demand task when energy source for the power harvesting module is more abundant.

[0023] In an example, the training period can correspond to the rated lifetime of the secondary battery. In at least one example, the training period can last at least one year to allow the controller to understand diurnal, seasonal and annual variations in energy availability and consumption to adapt accordingly. For example, less solar energy is available during the shorter daylight hours of winter than during the longer daylight hours of summer. In contrast, more wind may be available during winter storms than calmer summer days. The controller may alter the queue of tasks to execute energy demanding tasks following a period of supercapacitor recharging to maximize the harvesting of available energy. In an example, the controller may alter the queue of tasks to operate the IoT device to minimize energy consumption and energy demanding tasks until a charging period for the supercapacitor can be scheduled.

[0024] In an example, the IoT device may include a hybrid power circuit including a supercapacitor and a secondary battery arranged in parallel to discharge power to the device module. The hybrid power circuit may be biased such that the supercapacitor is the primary power source for the device module and draws power from the secondary battery when the supercapacitor is

depleted. In an example, during high energy demanding tasks such as transmission of information, the supercapacitor may initially power the device module and the secondary battery may power the device module when the supercapacitor is depleted. The controller may schedule energy demanding tasks to align with power harvesting windows such that the supercapacitor is continually recharged by the power harvesting module as the supercapacitor is discharged to avoid discharging the secondary battery. The controller may alter the queue of tasks to execute energy demanding tasks following a period of super capacitor recharging to maximize the harvesting of available energy and minimize use of the secondary battery. In an example, the controller may alter the queue of tasks to operate the IoT device to minimize energy consumption and energy demanding tasks until the supercapacitor can be recharged. As the secondary battery supplements the supercapacitor rather than operating as the primary power source, the secondary battery is discharged and recharged less frequently thereby extending the functional life of the battery and/or avoiding the reduced effective charge resulting from repeated recharging of the battery.

[0025] As depicted in FIGS. 1A to 1D, an IoT device 10, according to an example, may include an energy harvesting module 12, at least one supercapacitor 14 and at least one device module 16. The energy harvesting module 12 may be operably connected to the supercapacitor 14 for charging the supercapacitor 14, which is operably connected to each device module 16 for discharging power to each device module 16. In an example, a controller module 24 may be configured to control power distribution from the supercapacitor 14 to each device module 16. As depicted in FIGS. 2A-2C, in an example, an IC Boost may step up the voltage outputted by the energy harvesting module 12 to the supercapacitor 14.

[0026] In an example, the energy harvesting module 12 may be integrated into the IoT device 10 as depicted in FIG. 1A. In this configuration, the IoT device 10 can be self-contained and sealed to minimize potential entry points into the IoT device 10. In at least one example, the IoT device 10 may be mounted to an existing power grid or other energy harvesting devices in a parasitic fashion such that the energy harvesting module 12 draws power from the power grid or other energy harvesting devices to charge the supercapacitor 14.

[0027] In an example, as depicted in FIG. 1C, the energy harvesting module 12 may be remote from the supercapacitor 14, wherein the energy harvesting module 12 may be electrically connected to the supercapacitor 14 to charge the supercapacitor 14. In this configuration, the energy harvesting module 12 may be larger than an integrated energy harvesting module 12, thereby permitting gathering of energy from certain ambient energy sources that could require a larger energy gathering module 12 including, but not limited to solar, microwave, wind, water, and geothermal. Alternatively, in at least one example, the remotely positioned energy harvesting module 12 may be configured to draw from a power grid or other energy harvesting devices in a parasitic fashion to charge the supercapacitor 14.

[0028] In at least one example, the energy harvesting module 12 may be configured to convert into electrical energy at least one of, but not limited, mechanical motion, kinetic inductance, electromagnetic inductance, thermal energy, ambient temperature change, and electromagnetic radiation provided by ambient sources. The ambient sources can include, but are not limited to, solar energy, wind energy, tidal or hydroelectric energy, geothermal energy, hydro or air temperature change energy, magnetic energy, and nuclear energy.

[0029] In at least one example, the energy harvesting module 12 may be configured to generate electrical energy from a consumable fuel source. The fuel source may include, but is not limited to gasoline, diesel, natural gas, ethanol, coal, nuclear, biomass, salt, sand, and synthetic fuels. The energy harvesting module 12 may be configured to kinetic energy provided by a user to allow manual charging of the IoT device 10 as needed.

[0030] In at least one example, the energy harvesting module 12 may be configured to parasitically draw electricity from an existing electrical source including, but not limited to, an existing power grid or other energy harvesting or generators. In this configuration, the IoT device 10 can include a converter for varying the electricity drawn from the existing electrical source.

[0031] As depicted in FIG. 1D, in at least one example, the IoT device 10 can include at least a first energy harvesting module 12A and a second energy harvesting module 12B. The energy harvesting modules 12A, 12B may be configured to convert energy from the same energy source to increase the energy supplied and/or reduce the size of the energy harvesting modules 12A, 12B. In at

least one example, the energy harvesting modules 12A, 12B may be configured to convert energy from different energy sources to increase flexibility in timing and/or energy that can be supplied in recharging of the supercapacitor 14. As depicted in FIG. 1D, the energy harvesting module 12A may convert solar
5 energy and the energy harvesting module 12B may convert wind energy.

[0032] The supercapacitor 14 may comprise a wound or stacked capacitor wherein a plurality of electrode plates are arranged in parallel. In this configuration, each electrode sandwich may operate as an Electric Double Layer Capacitor (“EDLC”) to maximize the surface area to volume ratio of the
10 supercapacitor 14. In an at least one example, supercapacitor 14 may comprise a hybrid capacitor in addition to or in place of an EDLC. As illustrated, the IoT device 10 includes a single supercapacitor 14. It is contemplated that the IoT device 10 may include a plurality of supercapacitors 14 to increase the amount of power that may be stored by the supercapacitors 14. In this configuration, the
15 plurality of supercapacitors 14 may be arranged in parallel.

[0033] The device modules 16 may include, but are not limited to, a plurality of modules includes sensors, transmitters, receivers, data storage modules and other modules for IoT devices configured for long term monitoring. The device module 16 is intended to generally refer to the modules of IoT device
20 10 and is not intended to be limiting.

[0034] As depicted in FIG. 1A, the IoT device 10 may include a secondary battery 20 to provide a hybrid power supply that may supplement the supercapacitor 14. As illustrated in FIG. 1A, in an example, the energy harvesting module 12 may be operably connected to the secondary battery 20 for
25 charging the secondary battery 20, which discharges power to each device module 16. In at least one example, the IoT device 10 may be connectable to a DC source to recharge a depleted secondary battery 20. Alternatively, as illustrated in FIG. 1B, the secondary battery 20 may be a non-rechargeable battery, which may have a longer effective life than an equivalent rechargeable
30 battery. In this configuration, the IoT device 10 may be configured to permit swapping of a depleted secondary battery 20 with a charged secondary battery 20. The controller module 24 may be configured to control power distribution from the secondary battery 20 to each device module 16. In an example, the controller module 24 may be configured to direct power to each device module

16 from the supercapacitor 14 until the supercapacitor 14 is depleted. Upon depletion of the supercapacitor 14, the controller module 24 may be configured to direct power from the secondary battery 20 to each device module 16.

[0035] As depicted in FIG. 2A, a hybrid power circuit 25, according to an example, may include a primary power source path 26 and a battery source path 28. The primary power source path 26 may extend from the supercapacitor 14 to the device modules 16. In an example, the energy harvesting module 12 may be operably connected to the primary source path 26. The battery source path 28 may extend from the secondary battery 20 to the device modules 16.

[0036] A switching circuit 30 may be operably connected to the power source path 26 and the battery source path 28 and switch between the supercapacitor 14 and the secondary battery 20 as the power source for the device modules 16. The switching circuit 30 may include a comparator 32, a primary path metal-oxide-semiconductor field-effect transistor ("MOSFET") 34a, and a battery path MOSFET 34b for comparing the voltage supplied by the supercapacitor 14 and the secondary battery 20 and performing biased low-leakage switching between the supercapacitor 14 and the secondary battery 20.

[0037] As depicted in FIGS. 2A-C, in an example, the primary source path 26 may include a Schottky diode 36a for preventing inadvertent reverse power flows in the primary source path 26. The battery source path 28 may include a Schottky diode 36b for preventing inadvertent reverse power flows in the battery source path 28.

[0038] In an example, the output voltage of the supercapacitor 14 is greater than the output voltage of the secondary battery 20 such that the switching circuit 30 is biased toward the supercapacitor 14 and only supplies power from the secondary battery 20 when the supercapacitor 14 is sufficiently depleted. As illustrated in FIGS. 2B and 3, during high energy demand tasks, such as transmission of messages (e.g. Msg #1, Msg #2, Msg #3, Msg #4), the supercapacitor voltage V_{cap} may decrease as the supercapacitor 14 is depleted. The energy harvesting module 12 may recharge the supercapacitor 14 between the high energy demand tasks without or minimally relying on energy discharge from the secondary battery 20, as illustrated by the secondary battery voltage V_{batt} in FIG. 3. This arrangement avoids bursty current usage from the secondary battery 20, which extends the lifetime of the battery. As illustrated in FIGS. 2C

and 4, in situations where the energy harvesting module 12 cannot sufficiently recharge the supercapacitor 14 between the high energy tasks (e.g. unable to collect solar energy at night), the secondary battery 20 may provide supplemental energy for performing any intervening high energy demand task (Msg #3).

[0039] As illustrated in FIG. 5, a method for scheduling tasks 100 may include a task selection 102, a voltage comparison 104, and a total energy evaluation 106. This method 100 may be implemented by the controller 24. In an example, the controller 24 may be a microprocessor for receiving instructions from computer readable medium.

[0040] The task selection 102 may include querying a task queue of scheduled energy demanding tasks for the device modules 16 including, but not limited to, message transmission; message reception; sensor operation; and data collection. The task queue may comprise a chronological list of energy demanding tasks. For an example, the task queue can include collecting data with the sensor operation and transmitting the corresponding information to a remote receiver. In an example, the task queue can include performing certain energy demanding tasks at certain time frames. The energy demanding tasks and initial queue may be preprogrammed or received via message transmission from a remote controller.

[0041] The voltage comparison 104 may include comparing the output voltage V_{cap} of the supercapacitor 14 and the output voltage V_{batt} of the secondary battery 20 to determine if the output voltage V_{cap} exceeds the V_{batt} . If the V_{cap} does not exceed the V_{batt} , energy demanding task is rescheduled to the queue to delay the energy demanding task until either the supercapacitor 14 is sufficient to perform the energy demanding task. In an example, the energy demanding task can be designated as a high priority task. If designated as a high priority task, the controller may proceed to the total energy evaluation 106 and immediately supply power the available power to perform the energy demanding task even if the output voltage V_{cap} does not exceed the V_{batt} . As such, the secondary battery 20 can be discharged in the performance of high priority tasks if the output voltage V_{cap} is insufficient. High priority tasks may include, but are not limited to, message transmissions corresponding to detected emergency situations and detected IoT device 10 malfunctions or damage. High priority

tasks may include, but are not limited to, message transmissions corresponding to detected emergency situations and detected IoT device 10 malfunctions or damage. This configuration allows delaying high energy demand, low priority tasks to allow the supercapacitor 14 to be sufficiently charge to be the sole power provider for the scheduled task and avoid any discharge of the secondary battery 20. High energy demand, low priority tasks may include, but are not limited to, ordinary message transmissions and data uploads.

[0042] The total energy evaluation 106 may include evaluating the output voltage V_{cap} of the supercapacitor 14 and the output voltage V_{batt} of the secondary battery 20 to determine if sufficient power for performing the schedule energy demanding task may be provided from the supercapacitor 14, the secondary battery 20 and combination thereof. If the supercapacitor 14 and the secondary battery 20 cannot provide sufficient power, the energy demanding task is returned to the queue for performance later when either the supercapacitor 14 and/or the secondary battery 20 is sufficiently recharged. In an example, if the total energy evaluation 106 determines that insufficient power may be provided to perform the energy demanding task, the energy demanding task is returned to the task queue even if the energy demanding task is a high priority task. If sufficient power may be provided by the supercapacitor 14 and/or the secondary battery 20, the scheduled task may be performed if the energy demanding task is a high priority task. In at least one example, if the energy demanding task passes the voltage comparison 104, but insufficient power can be provided by the supercapacitor 14 and/or the secondary batter 20 when evaluated at the total energy evaluation 106.

[0043] In an example, if the secondary battery 20 is depleted, the voltage output V_{cap} of the supercapacitor 14 will always exceed the voltage output V_{batt} and the total energy evaluation 106 is the deciding step on whether the scheduled energy demanding task is performed or queued until the supercapacitor 14 is sufficiently charged. This configuration prolongs the effective life of the IoT device 10 by allowing the IoT device 10 to be used after the secondary battery 20 is depleted or the effective charge carried by the secondary battery 20 is reduced by repeated recharging.

[0044] As illustrated in FIG. 6, a method for evaluating secondary battery 20 usage 120 may include recording energy usage statistics 122; usage

comparison 124; and alert generation 126. As discussed above, regular recharging of a secondary battery 20 may reduce the effective charge that may be retained by the battery. Accordingly, the method 120 may be used to regularly evaluate the usage of the secondary battery 20 and alert the user is over
5 use of the secondary battery 20 may occur. This method 120 may be implemented by the controller 24. In an example, the controller 24 may be a microprocessor receiving instructions from computer readable medium.

[0045] The recording of energy usage statistics 122 may include collecting statistics on the usage of the supercapacitor 14 and the secondary
10 battery 20 over a predetermined period of time. The usage statistics may include, but are not limited to, the amount of power discharged; the duration of power discharge; the frequency of power discharge and the total power discharged during scheduled task.

[0046] The usage comparison 124 may include comparing the usage
15 duration of the supercapacitor 14 and the usage duration of the secondary battery 20. If the usage duration of the supercapacitor 14 exceeds the usage duration of the secondary battery 20, the method 120 is discontinued for a predetermined period and restarted after the period has passed. In an example, a different usage statistic may be used, such as, but not limited to, the amount of power
20 discharged; the frequency of power discharge and the total power discharged during scheduled task.

[0047] The alert generation 126 may include, upon determination that the usage of the secondary battery 20 exceeds the usage of the supercapacitor 14, generating of an alert. In an example, the alert may be telemetry data transmitted
25 to a remote receiver such that adjustments to the supercapacitor 14 or energy harvesting module 12 may be made if needed. A remote user may evaluate the received telemetry data and vary the scheduled tasks to reduce the energy consumption of the device modules 16. Alternatively, the capacity of the super
30 capacity 14 and/or the energy supply capabilities of the energy harvesting module 12 may be upgraded or adjusted in response to the received telemetry data. In at least one example, the controller 24 may adjust scheduling of tasks 100 to minimize the energy demands on the secondary battery 20.

[0048] FIG. 7 is a block diagram illustrating an example controller module 24 upon which any one or more of the methodologies herein discussed

may be run. In alternative embodiments, the machine operates as a standalone device or may be connected (e.g., networked) to other machines. In a networked deployment, the machine may operate in the capacity of either a server or a client machine in server-client network environments, or it may act as a peer machine in peer-to-peer (or distributed) network environments. The machine may be a personal computer (PC), a tablet PC, a set-top box (STB), a Personal Digital Assistant (PDA), a mobile telephone, a web appliance, a network router, switch or bridge, or any machine capable of executing instructions (sequential or otherwise) that specify actions to be taken by that machine. Further, while only a single machine is illustrated, the term "machine" shall also be taken to include any collection of machines that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methodologies discussed herein.

[0049] Example computer system 200 includes a processor 202 (e.g., a central processing unit (CPU), a graphics processing unit (GPU) or both), a main memory 201 and a static memory 206, which communicate with each other via a bus 208. The computer system 200 may further include a display unit 210, an alphanumeric input device 217 (e.g., a keyboard), and a user interface (UI) navigation device 211 (e.g., a mouse). In one embodiment, the display unit 210, input device 217 and UI navigation device 211 are a touch screen display. The computer system 200 may additionally include a storage device (e.g., drive unit) 216, a signal generation device 218 (e.g., a speaker), a network interface device 220, and one or more sensors 221, such as a global positioning system (GPS) sensor, compass, accelerometer, or other sensor.

[0050] The storage device 216 includes a machine-readable medium 222 on which is stored one or more sets of data structures and instructions 223 (e.g., software) embodying or utilized by any one or more of the methodologies or functions described herein. The instructions 223 may also reside, completely or at least partially, within the main memory 201 and/or within the processor 202 during execution thereof by the computer system 200, with the main memory 201 and the processor 202 also constituting machine-readable media.

[0051] While the machine-readable medium 222 is illustrated in an example embodiment to be a single medium, the term "machine-readable medium" may include 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 instructions 223. The term “machine-readable medium” shall also be taken to include any tangible medium that is capable of storing, encoding or carrying instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure or that is capable of storing, encoding or carrying data structures utilized by or associated with such instructions. The term “machine-readable medium” shall accordingly be taken to include, but not be limited to, solid-state memories, and optical and magnetic media. Specific examples of machine-readable media include non-volatile memory, including, by way of example, semiconductor memory devices (e.g., Electrically Programmable Read-Only Memory (EPROM), Electrically Erasable Programmable Read-Only Memory (EEPROM)) and flash memory devices; magnetic disks such as internal hard disks and removable disks; magneto-optical disks; and CD-ROM and DVD-ROM disks.

[0052] The instructions 223 may further be transmitted or received over a communications network 226 using a transmission medium via the network interface device 220 utilizing any one of a number of well-known transfer protocols (e.g., HTTP). Examples of communication networks include a local area network (LAN), a wide area network (WAN), the Internet, mobile telephone networks, Plain Old Telephone (POTS) networks, and wireless data networks (e.g., Wi-Fi® and WiMax® networks). The term “transmission medium” shall be taken to include any intangible medium that is capable of storing, encoding or carrying instructions for execution by the machine, and includes digital or analog communications signals or other intangible medium to facilitate communication of such software.

Various Notes & Examples

[0053] Example 1 is a system for powering a device module, the system comprising: an energy harvesting module; and a supercapacitor chargeable by the energy harvesting module; wherein the supercapacitor is configured to discharge power to the device module at a supercapacitor voltage.

[0054] In Example 2, the subject matter of Example 1 optionally includes, wherein the energy harvesting module is configured to collect energy from an ambient source, the ambient source comprising at least one of solar

panels, wind turbines, hydroelectric generators, tidal generators, kinetic induction generators, electromagnetic induction generators, geothermal generators, and heat pump generators.

[0055] In Example 3, the subject matter of any one or more of Examples 1–2 optionally include, wherein the energy harvesting module is configured to generate energy from a fuel source, the fuel source comprising at least one of gasoline generators, diesel generators, and natural gas generators.

[0056] In Example 4, the subject matter of any one or more of Examples 1–3 optionally include, wherein the system comprises: a supercapacitor bank including a plurality of supercapacitors arranged in parallel; wherein the plurality of supercapacitors are chargeable by the energy harvesting module and configured to discharge power to the device module.

[0057] In Example 5, the subject matter of any one or more of Examples 1–4 optionally include, wherein the supercapacitor operates as at least one of an electric double layer capacitor and a hybrid capacitor.

[0058] In Example 6, the subject matter of any one or more of Examples 1–5 optionally include, the system comprising: a controller selectively distributing power discharged by the supercapacitor to the device module.

[0059] In Example 7, the subject matter of Example 6 optionally includes, wherein the controller is configured to: identify at least one energy demanding task of the device module requiring power from the supercapacitor.

[0060] In Example 8, the subject matter of Example 7 optionally includes, wherein the controller is configured to: schedule the at least one energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module.

[0061] In Example 9, the subject matter of any one or more of Examples 7–8 optionally include, wherein the controller is configured to: schedule a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

[0062] In Example 10, the subject matter of any one or more of Examples 6–9 optionally include, wherein the controller is configured to: evaluate energy usage statistics for the supercapacitor, the energy usage statistics include at least one of amount of power discharged, duration of power discharge,

frequency of power discharge and total power discharged during the at least one energy demanding task; and generate an alert if the energy usage statistics indicate insufficient power for the at least one energy demanding task.

[0063] In Example 11, the subject matter of any one or more of
5 Examples 1–10 optionally include, further comprising: a secondary battery configured to discharge power to the device module at a battery voltage.

[0064] In Example 12, the subject matter of Example 11 optionally includes, wherein the supercapacitor and the secondary battery are arranged in parallel.

10 [0065] In Example 13, the subject matter of any one or more of Examples 9–12 optionally include, wherein the supercapacitor voltage is greater than the battery voltage such that power output to the device module is biased to the supercapacitor until the supercapacitor is discharged.

[0066] In Example 14, the subject matter of any one or more of
15 Examples 11–13 optionally include, further comprising: a controller selectively distributing power discharged by at least one of the supercapacitor and the secondary battery to the device module.

[0067] In Example 15, the subject matter of Example 14 optionally includes, wherein the controller is configured to: compare the supercapacitor
20 voltage to the battery voltage; and discharge power from the supercapacitor to the device module when the supercapacitor voltage exceeds the battery voltage.

[0068] In Example 16, the subject matter of any one or more of Examples 14–15 optionally include, wherein the controller is configured to:
25 evaluate supercapacitor voltage and the battery voltage to determine an available charge of the supercapacitor and the secondary battery; and discharge power from the supercapacitor and the secondary battery when the available charge is sufficient to power the device module.

[0069] In Example 17, the subject matter of any one or more of Examples 14–16 optionally include, wherein the controller is configured to:
30 identify at least one energy demanding task of the device module; and selectively discharge power from at least one of the supercapacitor and the secondary battery.

[0070] In Example 18, the subject matter of Example 17 optionally includes, wherein the controller is configured to: compare the supercapacitor

voltage to the battery voltage; and delay the at least one energy demanding task when the battery voltage exceeds the supercapacitor voltage until the supercapacitor is recharged by the energy harvesting module.

[0071] In Example 19, the subject matter of any one or more of Examples 17–18 optionally include, wherein the controller is configured to: compare the supercapacitor voltage to the battery voltage; and schedule the at least one energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module when the battery voltage exceeds the supercapacitor voltage.

10 [0072] In Example 20, the subject matter of any one or more of Examples 17–19 optionally include, wherein the controller is configured to: schedule a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

15 [0073] In Example 21, the subject matter of any one or more of Examples 17–20 optionally include, wherein the controller is configured to: evaluate supercapacitor voltage and the battery voltage to determine an available charge of the supercapacitor and the secondary battery; and delay the at least one energy demanding task when the available charge is insufficient to perform the at least one energy demanding task.

[0074] In Example 22, the subject matter of any one or more of Examples 14–21 optionally include, wherein the controller is configured to: evaluate energy usage statistics for the supercapacitor and the secondary battery, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task.

25 [0075] In Example 23, the subject matter of Example 22 optionally includes, wherein the controller is configured to: generate an alert if the collected energy usage statistics indicate that usage of the secondary battery exceeds usage of the supercapacitor.

[0076] In Example 24, the subject matter of Example 23 optionally includes, further comprising: a transmitter module; and a remote receiver;

wherein the alert comprises telemetry data transmittable to the remote receiver by the transmitter module for evaluating the received telemetry data.

[0077] In Example 25, the subject matter of any one or more of Examples 14–24 optionally include, further comprising: a receiver module;
5 wherein the controller is configured to receive instructions via the receiver module to modify power discharge from at least one the supercapacitor and the secondary battery.

[0078] Example 26 is a method for powering a device module, the method comprising: generating energy with an energy harvesting module;
10 charging a supercapacitor with energy generated by the energy harvesting module; and discharging power from the supercapacitor to the device module at a supercapacitor voltage.

[0079] In Example 27, the subject matter of Example 26 optionally includes, wherein the energy harvesting module generates energy by collecting
15 energy from an ambient source and comprises at least one of solar panels, wind turbines, hydroelectric generators, tidal generators, kinetic induction generators, electromagnetic induction generators, geothermal generators, and heat pump generators.

[0080] In Example 28, the subject matter of any one or more of Examples 26–27 optionally include, wherein the energy harvesting module
20 generates energy from a fuel source selected and comprises at least one of gasoline generators, diesel generators, and natural gas generators.

[0081] In Example 29, the subject matter of any one or more of Examples 26–28 optionally include, wherein the energy harvesting module
25 charges a supercapacitor bank including a plurality of supercapacitors arranged in parallel, the plurality of supercapacitors are configured to discharge power to the device module.

[0082] In Example 30, the subject matter of any one or more of Examples 26–29 optionally include, wherein the supercapacitor operates as at
30 least one of an electric double layer capacitor and a hybrid capacitor.

[0083] In Example 31, the subject matter of any one or more of Examples 26–30 optionally include, further comprising: selectively distributing power discharge from the supercapacitor according to power usage of the device module.

[0084] In Example 32, the subject matter of any one or more of Examples 26–31 optionally include, further comprising: identifying at least one energy demanding task of the device module requiring power from the supercapacitor.

- 5 [0085] In Example 33, the subject matter of Example 32 optionally includes, further comprising: scheduling the at least one energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module.

- [0086] In Example 34, the subject matter of any one or more of
10 Examples 32–33 optionally include, further comprising: scheduling a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

- [0087] In Example 35, the subject matter of any one or more of
15 Examples 32–34 optionally include, further comprising: evaluating energy usage statistics for the supercapacitor, wherein the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task; and generating an alert if the energy usage statistics
20 indicate insufficient power for the at least one energy demanding task.

[0088] In Example 36, the subject matter of any one or more of Examples 26–35 optionally include, further comprising: discharging power from a secondary battery to the device module at a battery voltage.

- [0089] In Example 37, the subject matter of Example 36 optionally
25 includes, wherein the supercapacitor and the secondary battery are arranged in parallel.

- [0090] In Example 38, the subject matter of Example 37 optionally includes, wherein the supercapacitor voltage is greater than the battery voltage such that power output to the device module is biased to the supercapacitor until
30 the supercapacitor is discharged.

[0091] In Example 39, the subject matter of any one or more of Examples 36–38 optionally include, further comprising: selectively distributing power discharge from at least one of the supercapacitor and the secondary battery according to power usage of the device module.

[0092] In Example 40, the subject matter of any one or more of Examples 36–39 optionally include, further comprising: comparing the supercapacitor voltage to the battery voltage; and discharging power from the supercapacitor to the device module when the supercapacitor voltage exceeds the battery voltage.

[0093] In Example 41, the subject matter of any one or more of Examples 36–40 optionally include, further comprising: evaluating supercapacitor voltage and the battery voltage to determine an available charge of the supercapacitor and the secondary battery; and discharging power from the supercapacitor and the secondary battery when the available charge is sufficient to power the device module.

[0094] In Example 42, the subject matter of any one or more of Examples 36–41 optionally include, further comprising: identifying at least one energy demanding task of the device module; and selectively discharging power from at least one of the supercapacitor and the secondary battery.

[0095] In Example 43, the subject matter of Example 42 optionally includes, further comprising: comparing the supercapacitor voltage to the battery voltage; and delaying the at least one energy demanding task when the battery voltage exceeds the supercapacitor voltage until the supercapacitor is recharged by the energy harvesting module.

[0096] In Example 44, the subject matter of any one or more of Examples 42–43 optionally include further comprising: comparing the supercapacitor voltage to the battery voltage; and scheduling the at least one energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module when the battery voltage exceeds the supercapacitor voltage.

[0097] In Example 45, the subject matter of any one or more of Examples 42–44 optionally include, further comprising: scheduling a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

[0098] In Example 46, the subject matter of any one or more of Examples 42–45 optionally include, further comprising: evaluating supercapacitor voltage and the battery voltage to determine an available charge

of the supercapacitor and the secondary battery; and delaying the at least one energy demanding task when the available charge is insufficient to perform the at least one energy demanding task.

- [0099] In Example 47, the subject matter of any one or more of
- 5 Examples 36–46 optionally include, further comprising: evaluating energy usage statistics for the supercapacitor and the secondary battery, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task.
- 10 [00100] In Example 48, the subject matter of Example 47 optionally includes, further comprising: generating an alert if the collected energy usage statistics indicate that usage of the secondary battery exceeds usage of the supercapacitor.
- [00101] In Example 49, the subject matter of Example 48 optionally
- 15 includes, further comprising: transmitting the alert to a remote receiver by a transmitter module, wherein the alert comprises telemetry data; and evaluating the received telemetry data.
- [00102] In Example 50, the subject matter of any one or more of
- 20 Examples 36–49 optionally include, further comprising: receiving instructions to modify power discharge from the supercapacitor and the secondary battery.
- [00103] Example 51 is an apparatus comprising means for performing any of the methods of Examples 26–50.
- [00104] Example 52 is at least one machine-readable medium including instructions, which when executed by a machine, cause the machine to perform
- 25 operations of any of the methods of Examples 26–50.
- [00105] Example 53 is an apparatus for powering a device module, the apparatus comprising: means for generating energy with an energy harvesting module; means for charging a supercapacitor with energy generated by the energy harvesting module; and means for discharging power from the
- 30 supercapacitor to the device module at a supercapacitor voltage.
- [00106] In Example 54, the subject matter of Example 53 optionally includes, wherein the energy harvesting module is configured to collect energy from an ambient source and comprises at least one of solar panels, wind turbines, hydroelectric generators, tidal generators, kinetic induction generators,

electromagnetic induction generators, geothermal generators, and heat pump generators.

[00107] In Example 55, the subject matter of any one or more of Examples 53–54 optionally include, wherein the energy harvesting module is
5 configured to generate energy from a fuel source and comprises at least one of gasoline generators, diesel generators, and natural gas generators.

[00108] In Example 56, the subject matter of any one or more of Examples 53–55 optionally include, wherein the apparatus comprises: a
10 supercapacitor bank including a plurality of supercapacitors arranged in parallel; wherein the plurality of supercapacitors are chargeable by the energy harvesting module and configured to discharge power to the device module.

[00109] In Example 57, the subject matter of any one or more of Examples 53–56 optionally include, wherein the supercapacitor operates as at least one of an electric double layer capacitor and a hybrid capacitor.

15 [00110] In Example 58, the subject matter of any one or more of Examples 53–57 optionally include, further comprising: means for selectively distributing power discharge from the supercapacitor according to power usage of the device module.

[00111] In Example 59, the subject matter of Example 58 optionally
20 includes, further comprising: means for identifying at least one energy demanding task of the device module requiring power from the supercapacitor.

[00112] In Example 60, the subject matter of any one or more of Examples 58–59 optionally include, further comprising: means for scheduling the at least one energy demanding task such that the supercapacitor discharges
25 power to the device module as the supercapacitor is being charged by the energy harvesting module.

[00113] In Example 61, the subject matter of any one or more of Examples 58–60 optionally include, further comprising: means for scheduling a charging period following power discharge from the supercapacitor during the at
30 least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

[00114] In Example 62, the subject matter of any one or more of Examples 58–61 optionally include, further comprising: means evaluating energy usage statistics for the supercapacitor, the energy usage statistics include

at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task; and means for generating an alert if the energy usage statistics indicate insufficient power for the at least one energy demanding task.

5 [00115] In Example 63, the subject matter of any one or more of Examples 53–62 optionally include, further comprising: means for discharging power from a secondary battery to the device module at a battery voltage.

[00116] In Example 64, the subject matter of Example 63 optionally includes, wherein the supercapacitor voltage is greater than the battery voltage
10 such that power output to the device module is biased to the supercapacitor until the supercapacitor is discharged.

[00117] In Example 65, the subject matter of Example 64 optionally includes, wherein the supercapacitor voltage is greater than the battery voltage to bias power output to the device module to the supercapacitor until the
15 supercapacitor is discharged.

[00118] In Example 66, the subject matter of any one or more of Examples 63–65 optionally include, further comprising: means for selectively distributing power discharge from at least one of the supercapacitor and the secondary battery according to power usage of the device module.

20 [00119] In Example 67, the subject matter of Example 66 optionally includes, further comprising: means for comparing the supercapacitor voltage to the battery voltage; and means for discharging power from the supercapacitor to the device module when the supercapacitor voltage exceeds the battery voltage.

[00120] In Example 68, the subject matter of any one or more of
25 Examples 66–67 optionally include, further comprising: means for comparing the supercapacitor voltage to the battery voltage; and means for discharging power from the supercapacitor and the secondary battery when the available charge is sufficient to power the device module.

[00121] In Example 69, the subject matter of any one or more of
30 Examples 66–68 optionally include, further comprising: means for identifying at least one energy demanding task of the device module; and means for selectively discharging power from at least one of the supercapacitor and the secondary battery.

[00122] In Example 70, the subject matter of Example 69 optionally includes, further comprising: means for comparing the supercapacitor voltage to the battery voltage; and means for delaying the at least one energy demanding task when the battery voltage exceeds the supercapacitor voltage until the
5 supercapacitor is recharged by the energy harvesting module.

[00123] In Example 71, the subject matter of any one or more of Examples 69–70 optionally include, further comprising: means for comparing the supercapacitor voltage to the battery voltage; and means for scheduling the at least one energy demanding task such that the supercapacitor discharges power
10 to the device module as the supercapacitor is being charged by the energy harvesting module when the battery voltage exceeds the supercapacitor voltage.

[00124] In Example 72, the subject matter of any one or more of Examples 69–71 optionally include, further comprising: means for scheduling a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the
15 energy harvesting module following the at least one energy demanding task.

[00125] In Example 73, the subject matter of any one or more of Examples 69–72 optionally include, further comprising: means for evaluating supercapacitor voltage and the battery voltage to determine an available charge
20 of the supercapacitor and the secondary battery; and means for delaying the at least one energy demanding task when the available charge is insufficient to perform the at least one energy demanding task.

[00126] In Example 74, the subject matter of any one or more of Examples 66–73 optionally include, wherein the controller is configured to:
25 means for evaluating energy usage statistics for the supercapacitor and the secondary battery, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task.

[00127] In Example 75, the subject matter of Example 74 optionally includes, wherein the controller is configured to: means for generating an alert if
30 the collected energy usage statistics indicate that usage of the secondary battery exceeds usage of the supercapacitor.

[00128] In Example 76, the subject matter of Example 75 optionally includes, further comprising: means for transmitting the alert to a remote

receiver by a transmitter module, wherein the alert comprises telemetry data; and means for evaluating the received telemetry data.

[00129] In Example 77, the subject matter of Example 76 optionally includes, further comprising: means for receiving instructions to modify power
5 discharge from the supercapacitor and the secondary battery.

[00130] Example 78 is a system for powering a device module, the system comprising: a controller configured to read computer readable instructions and configured to control powering of the device module.

[00131] In Example 79, the subject matter of Example 78 optionally
10 includes, wherein the energy harvesting module is configured to collect energy from an ambient source and comprises at least one of solar panels, wind turbines, hydroelectric generators, tidal generators, kinetic induction generators, electromagnetic induction generators, geothermal generators, and heat pump generators.

[00132] In Example 80, the subject matter of any one or more of
15 Examples 78–79 optionally include, wherein the energy harvesting module is configured to generate energy from a fuel source and comprises at least one of gasoline generators, diesel generators, and natural gas generators.

[00133] In Example 81, the subject matter of any one or more of
20 Examples 78–80 optionally include, wherein the system comprises: a supercapacitor bank including a plurality of supercapacitors arranged in parallel; wherein the plurality of supercapacitors are chargeable by the energy harvesting module and configured to discharge power to the device module.

[00134] In Example 82, the subject matter of any one or more of
25 Examples 78–81 optionally include, wherein the supercapacitor operates as at least one of an electric double layer capacitor and a hybrid capacitor.

[00135] In Example 83, the subject matter of any one or more of
Examples 78–82 optionally include, wherein the instructions for controlling
powering of a device module comprises instructions for: selectively distributing
30 power discharge from the supercapacitor according to power usage of the device module.

[00136] In Example 84, the subject matter of Example 83 optionally includes, wherein the instructions for controlling powering of a device module

comprises instructions for: identifying at least one energy demanding task of the device module requiring power from the supercapacitor.

[00137] In Example 85, the subject matter of Example 84 optionally includes, wherein the instructions for controlling powering of a device module
5 comprises instructions for: scheduling the at least one energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module.

[00138] In Example 86, the subject matter of any one or more of Examples 84–85 optionally include, wherein the instructions for controlling
10 powering of a device module comprises instructions for: scheduling a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

[00139] In Example 87, the subject matter of any one or more of Examples 83–86 optionally include, wherein the instructions for controlling
15 powering of a device module comprises instructions for: evaluating energy usage statistics for the supercapacitor, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task; and generating an alert if the energy usage statistics indicate insufficient
20 power for the at least one energy demanding task.

[00140] In Example 88, the subject matter of any one or more of Examples 78–87 optionally include, further comprising: discharging power from a secondary battery to the device module at a battery voltage.

[00141] In Example 89, the subject matter of Example 88 optionally includes, wherein the supercapacitor and the secondary battery are arranged in parallel.

[00142] In Example 90, the subject matter of Example 89 optionally includes, wherein the supercapacitor voltage is greater than the battery voltage
30 such that power output to the device module is biased to the supercapacitor until the supercapacitor is discharged.

[00143] In Example 91, the subject matter of any one or more of Examples 88–90 optionally include, wherein the instructions for controlling powering of a device module comprises instructions for: selectively distributing

power discharge from at least one of the supercapacitor and the secondary battery according to power usage of the device module.

[00144] In Example 92, the subject matter of Example 91 optionally includes, wherein the instructions for controlling powering of a device module
5 comprises instructions for: comparing the supercapacitor voltage to the battery voltage; and discharging power from the supercapacitor to the device module when the supercapacitor voltage exceeds the battery voltage.

[00145] In Example 93, the subject matter of any one or more of Examples 91–92 optionally include, wherein the instructions for controlling
10 powering of a device module comprises instructions for: evaluating supercapacitor voltage and the battery voltage to determine an available charge of the supercapacitor and the secondary battery; and discharging power from the supercapacitor and the secondary battery when the available charge is sufficient to power the device module.

[00146] In Example 94, the subject matter of any one or more of Examples 91–93 optionally include, wherein the instructions for controlling
15 powering of a device module comprises instructions for: identifying at least one energy demanding task of the device module; and selectively discharging power from at least one of the supercapacitor and the secondary battery.

[00147] In Example 95, the subject matter of Example 94 optionally includes, wherein the instructions for controlling powering of a device module
20 comprises instructions for: comparing the supercapacitor voltage to the battery voltage; and delaying the at least one energy demanding task when the battery voltage exceeds the supercapacitor voltage until the supercapacitor is recharged by the energy harvesting module.

[00148] In Example 96, the subject matter of any one or more of Examples 94–95 optionally include, wherein the instructions for controlling
powering of a device module comprises instructions for: comparing the supercapacitor voltage to the battery voltage; and scheduling the at least one
30 energy demanding task such that the supercapacitor discharges power to the device module as the supercapacitor is being charged by the energy harvesting module when the battery voltage exceeds the supercapacitor voltage.

[00149] In Example 97, the subject matter of any one or more of Examples 94–96 optionally include, wherein the instructions for controlling

powering of a device module comprises instructions for: scheduling a charging period following power discharge from the supercapacitor during the at least one energy demanding task such that the supercapacitor is recharged by the energy harvesting module following the at least one energy demanding task.

- 5 **[00150]** In Example 98, the subject matter of any one or more of Examples 94–97 optionally include, wherein the instructions for controlling powering of a device module comprises instructions for: evaluating supercapacitor voltage and the battery voltage to determine an available charge of the supercapacitor and the secondary battery; and delaying the at least one
10 energy demanding task when the available charge is insufficient to perform the at least one energy demanding task.

- [00151]** In Example 99, the subject matter of any one or more of Examples 91–98 optionally include, wherein the instructions for controlling powering of a device module comprises instructions for: evaluating energy usage
15 statistics for the supercapacitor and the secondary battery, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task.

- [00152]** In Example 100, the subject matter of Example 99 optionally
20 includes, wherein the instructions for controlling powering of a device module comprises instructions for: generating an alert if the collected energy usage statistics indicate that usage of the secondary battery exceeds usage of the supercapacitor.

- [00153]** In Example 101, the subject matter of Example 100 optionally
25 includes, wherein the instructions for controlling powering of a device module comprises instructions for: transmitting the alert to a remote receiver by a transmitter module, wherein the alert comprises telemetry data; and evaluating the received telemetry data.

- [00154]** In Example 102, the subject matter of any one or more of
30 Examples 91–101 optionally include, wherein the instructions for controlling powering of a device module comprises instructions for: receiving instructions to modify power discharge from the supercapacitor and the secondary battery.

[00155] Each of these non-limiting examples may stand on its own, or may be combined in any permutation or combination with any one or more of the other examples.

[00156] The above detailed description includes references to the accompanying drawings, which form a part of the detailed description. The drawings show, by way of illustration, specific embodiments in which the present subject matter may be practiced. These embodiments are also referred to herein as “examples.” Such examples may include elements in addition to those shown or described. However, the present inventors also contemplate examples in which only those elements shown or described are provided. Moreover, the present inventors also contemplate examples using any combination or permutation of those elements shown or described (or one or more aspects thereof), either with respect to a particular example (or one or more aspects thereof), or with respect to other examples (or one or more aspects thereof) shown or described herein.

[00157] In the event of inconsistent usages between this document and any documents so incorporated by reference, the usage in this document controls.

[00158] In this document, the terms “a” or “an” are used, as is common in patent documents, to include one or more than one, independent of any other instances or usages of “at least one” or “one or more.” In this document, the term “or” is used to refer to a nonexclusive or, such that “A or B” includes “A but not B,” “B but not A,” and “A and B,” unless otherwise indicated. In this document, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Also, in the following claims, the terms “including” and “comprising” are open-ended, that is, a system, device, article, composition, formulation, or process that includes elements in addition to those listed after such a term in a claim are still deemed to fall within the scope of that claim. Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects.

[00159] Method examples described herein may be machine or computer-implemented at least in part. Some examples may include a computer-readable medium or machine-readable medium encoded with instructions operable to

configure an electronic device to perform methods as described in the above examples. An implementation of such methods may include code, such as microcode, assembly language code, a higher-level language code, or the like. Such code may include computer readable instructions for performing various methods. The code may form portions of computer program products. Further, in an example, the code may be tangibly stored on one or more volatile, non-transitory, or non-volatile tangible computer-readable media, such as during execution or at other times. Examples of these tangible computer-readable media may include, but are not limited to, hard disks, removable magnetic disks, removable optical disks (e.g., compact disks and digital video disks), magnetic cassettes, memory cards or sticks, random access memories (RAMs), read only memories (ROMs), and the like.

[00160] The above description is intended to be illustrative, and not restrictive. For example, the above-described examples (or one or more aspects thereof) may be used in combination with each other. Other embodiments may be used, such as by one of ordinary skill in the art upon reviewing the above description. The Abstract is provided to comply with 37 C.F.R. §1.72(b), to allow the reader to quickly ascertain the nature of the technical disclosure. It is submitted with the understanding that it will not be used to interpret or limit the scope or meaning of the claims. Also, in the above Detailed Description, various features may be grouped together to streamline the disclosure. This should not be interpreted as intending that an unclaimed disclosed feature is essential to any claim. Rather, inventive subject matter may lie in less than all features of a particular disclosed embodiment. Thus, the following claims are hereby incorporated into the Detailed Description as examples or embodiments, with each claim standing on its own as a separate embodiment, and it is contemplated that such embodiments may be combined with each other in various combinations or permutations. The scope of the present subject matter should be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled.

WHAT IS CLAIMED IS:

1. A system for powering a device module, the system comprising:
an energy harvesting module; and
5 a super capacitor chargeable by the energy harvesting module;
wherein the super capacitor is configured to discharge power to the
device module at a super capacitor voltage.
2. The system of claim 1, wherein the energy harvesting module is
10 configured to collect energy from an ambient source, the ambient source
comprising at least one of solar panels, wind turbines, hydroelectric generators,
tidal generators, kinetic induction generators, electromagnetic induction
generators, geothermal generators, and heat pump generators.
- 15 3. The system of claim 1, wherein the energy harvesting module is
configured to generate energy from a fuel source, the fuel source comprising at
least one of gasoline generators, diesel generators, and natural gas generators.
4. The system of claim 1, wherein the system comprises:
20 a super capacitor bank including a plurality of super capacitors arranged
in parallel;
wherein the plurality of super capacitors are chargeable by the energy
harvesting module and configured to discharge power to the device module.
- 25 5. The system of claim 1, wherein the super capacitor operates as at least
one of an electric double layer capacitor and a hybrid capacitor.
6. The system of claim 1, further comprising:
a secondary battery configured to discharge power to the device module
30 at a battery voltage.
7. The system of claim 6, wherein the super capacitor and the secondary
battery are arranged in parallel.

8. The system of claim 7, wherein the super capacitor voltage is greater than the battery voltage such that power output to the device module is biased to the super capacitor until the super capacitor is discharged.
- 5 9. The system of claim 6, further comprising:
a controller selectively distributing power discharged by at least one of the super capacitor and the secondary battery to the device module.
- 10 10. The system of claim 9, wherein the controller is configured to:
evaluate energy usage statistics for the super capacitor and the secondary battery, the energy usage statistics include at least one of amount of power discharged, duration of power discharge, frequency of power discharge and total power discharged during the at least one energy demanding task.
- 15 11. The system of claim 10, wherein the controller is configured to:
generate an alert if the collected energy usage statistics indicate that usage of the secondary battery exceeds usage of the super capacitor.
- 20 12. The system of claim 11, further comprising:
a transmitter module; and
a remote receiver;
wherein the alert comprises telemetry data transmittable to the remote receiver by the transmitter module for evaluating the received telemetry data.
- 25 13. The system of claim 9, further comprising:
a receiver module;
wherein the controller is configured to receive instructions via the receiver module to modify power discharge from at least one the super capacitor and the secondary battery.
- 30 14. A method for powering a device module, the method comprising:
generating energy with an energy harvesting module;
charging a super capacitor with energy generated by the energy harvesting module; and

discharging power from the super capacitor to the device module at a super capacitor voltage.

15. The method of claim 14, further comprising:
5 identifying at least one energy demanding task of the device module requiring power from the super capacitor.

16. The method of claim 15, further comprising:
scheduling the at least one energy demanding task such that the super
10 capacitor discharges power to the device module as the super capacitor is being charged by the energy harvesting module.

17. The method of claim 15, further comprising:
scheduling a charging period following power discharge from the super
15 capacitor during the at least one energy demanding task such that the super capacitor is recharged by the energy harvesting module following the at least one energy demanding task.

18. The method of claim 14, further comprising:
20 discharging power from a secondary battery to the device module at a battery voltage.

19. The method of claim 18, further comprising:
comparing the super capacitor voltage to the battery voltage; and
25 discharging power from the super capacitor to the device module when the super capacitor voltage exceeds the battery voltage.

20. The method of claim 18, further comprising:
evaluating super capacitor voltage and the battery voltage to determine an
30 available charge of the super capacitor and the secondary battery; and discharging power from the super capacitor and the secondary battery when the available charge is sufficient to power the device module.

21. The method of claim 18, further comprising:
identifying at least one energy demanding task of the device module; and
selectively discharging power from at least one of the super capacitor and the
secondary battery.

5

22. The method of claim 21, further comprising:
comparing the super capacitor voltage to the battery voltage; and
delaying the at least one energy demanding task when the battery voltage
exceeds the super capacitor voltage until the super capacitor is recharged by the
energy harvesting module.

10

23. The method of claim 21, further comprising:
comparing the super capacitor voltage to the battery voltage; and
scheduling the at least one energy demanding task such that the super capacitor
discharges power to the device module as the super capacitor is being charged
by the energy harvesting module when the battery voltage exceeds the super
capacitor voltage.

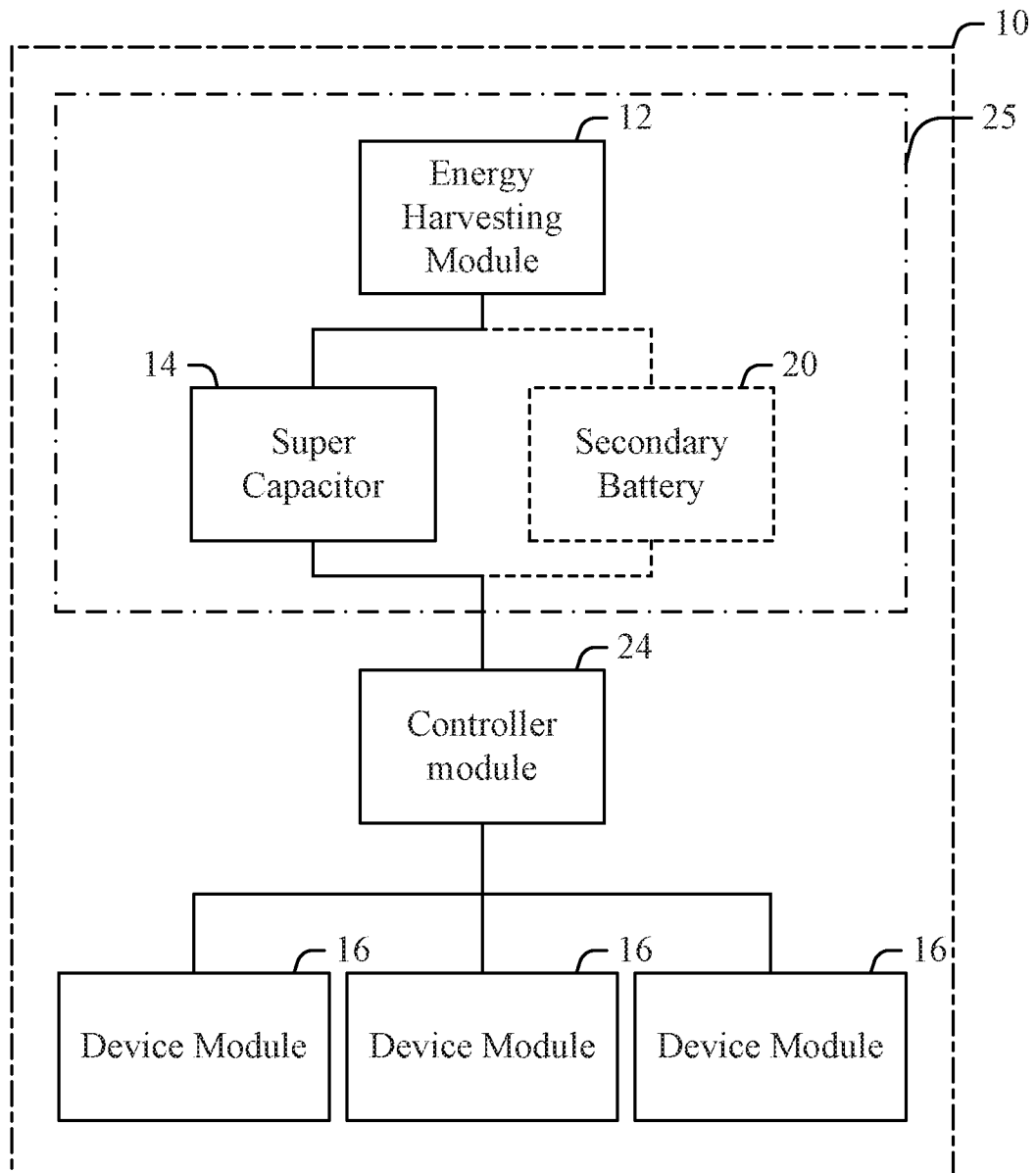
15

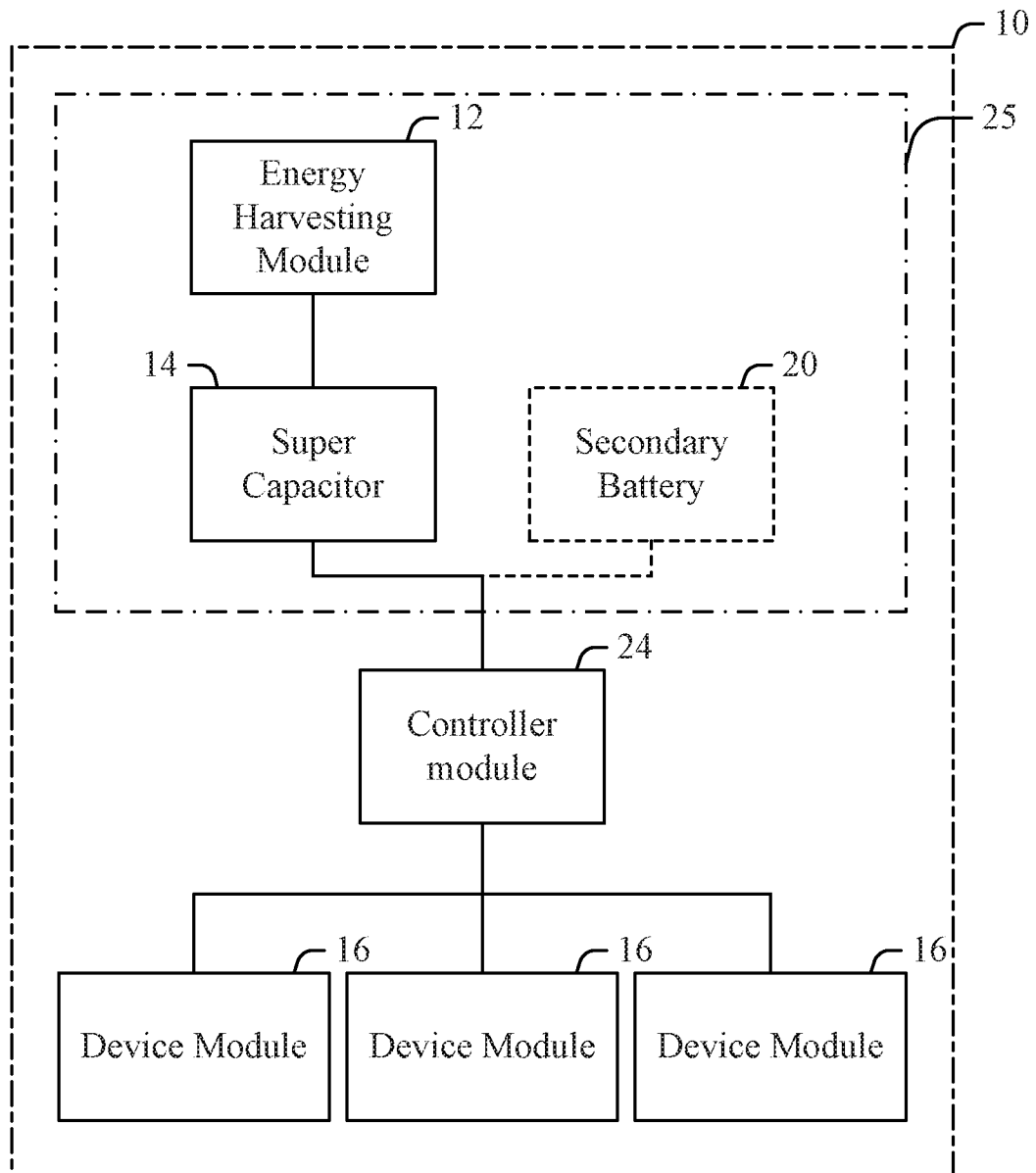
24. An apparatus comprising means for performing any of the methods of
claims 14-23.

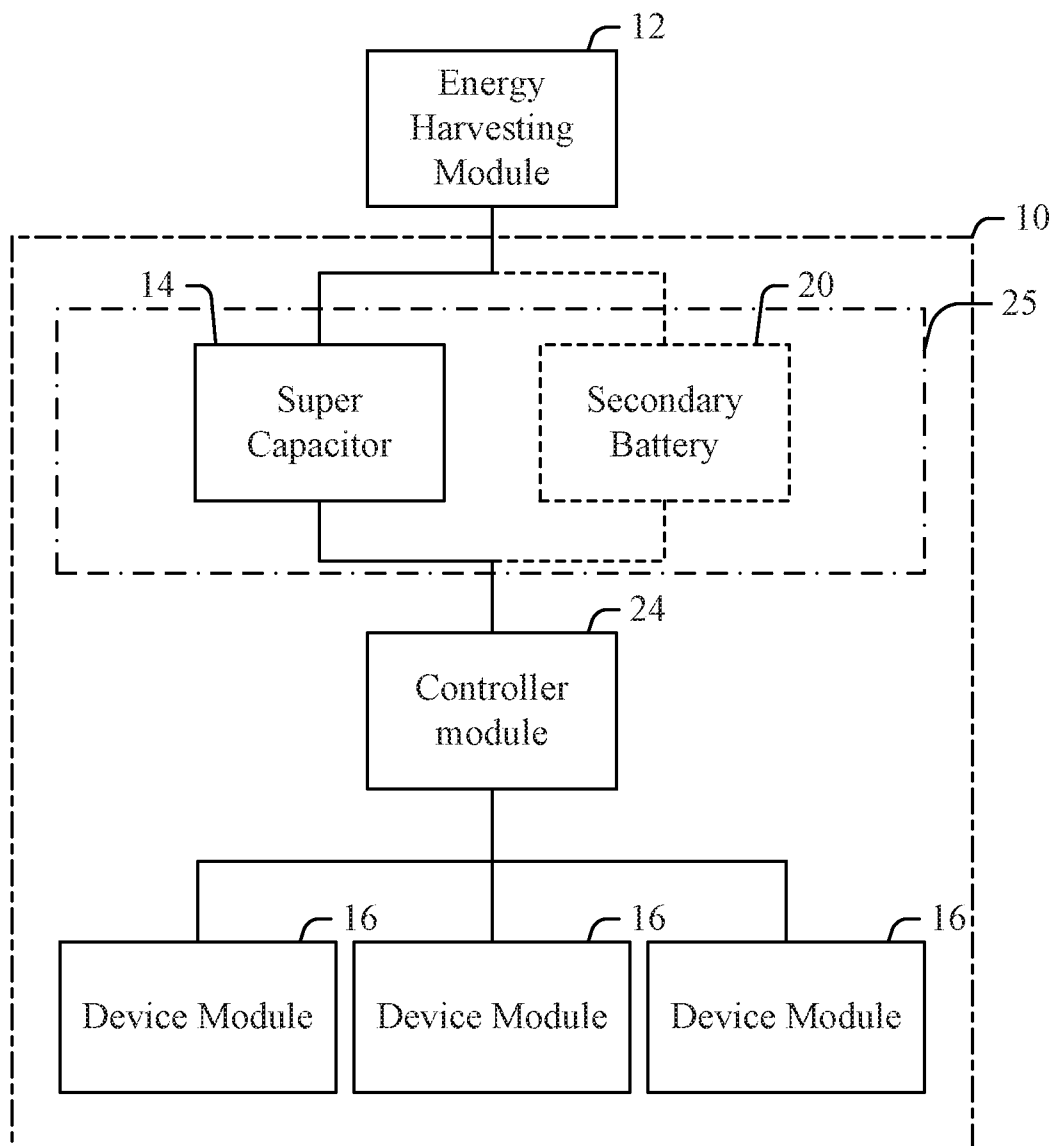
20

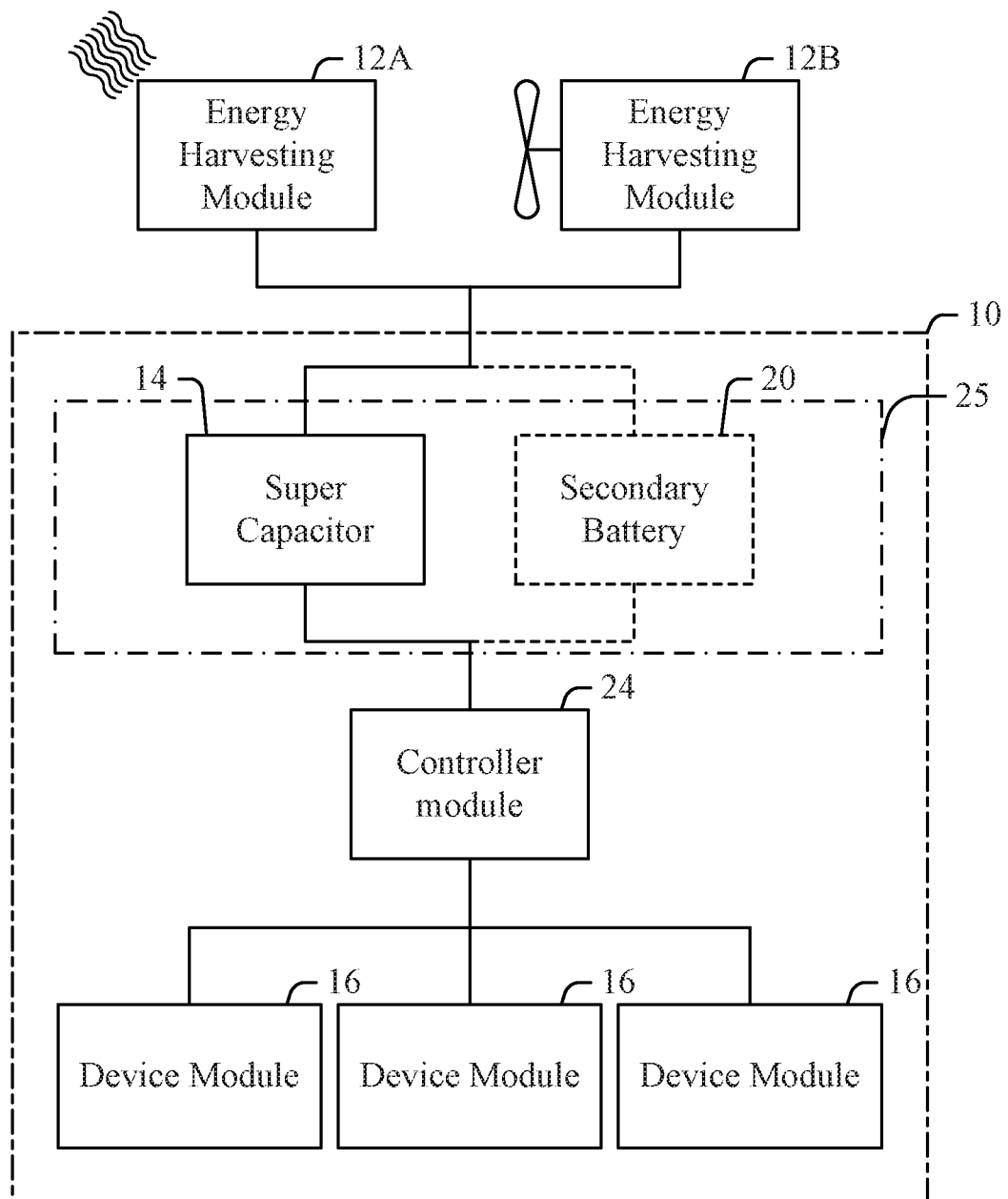
25. At least one machine-readable medium including instructions, which
when executed by a machine, cause the machine to perform operations of any of
the methods of claims 14-23.

25

**FIG. 1A**

**FIG. 1B**

**FIG. 1C**

**FIG. 1D**

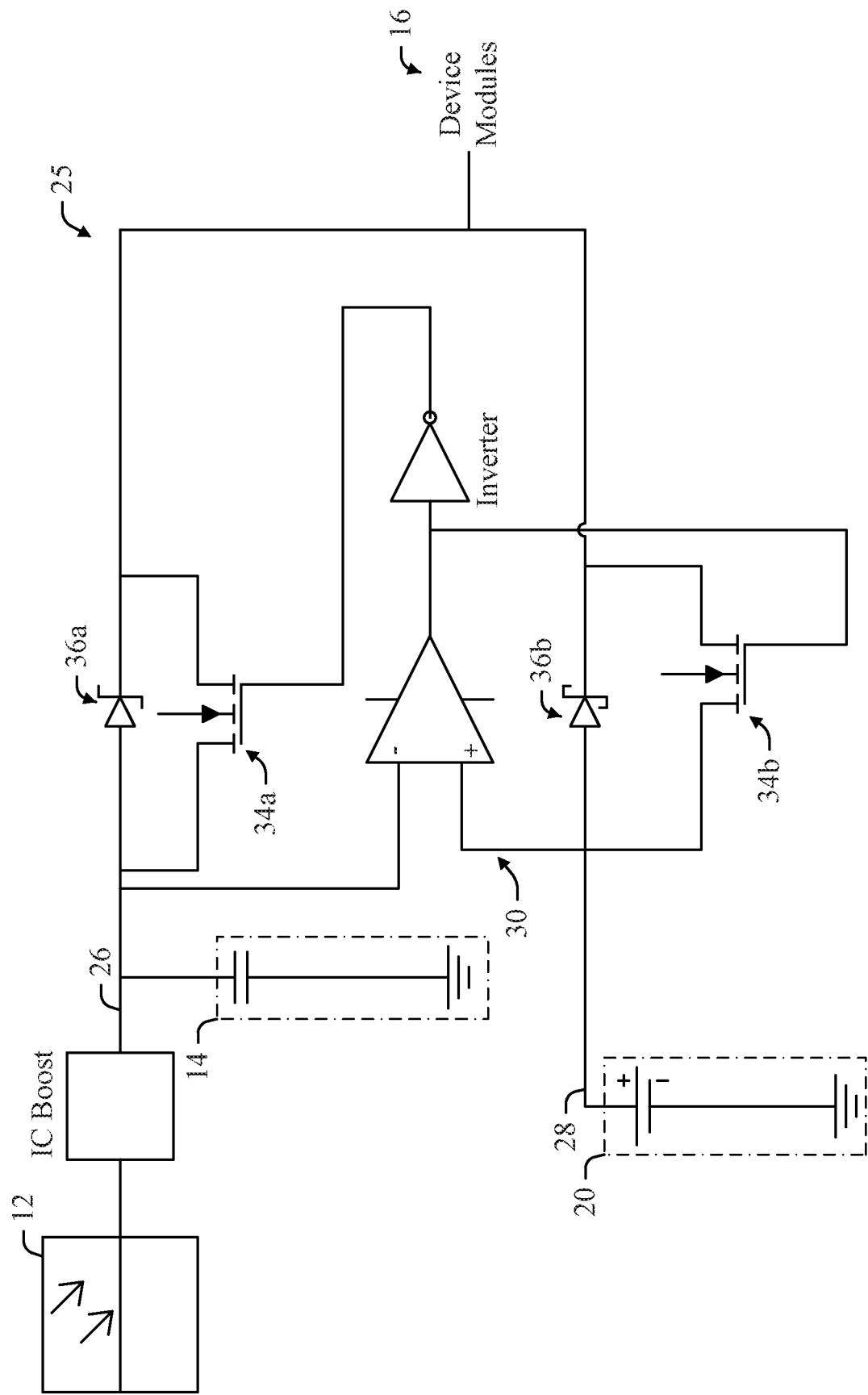


FIG. 2A

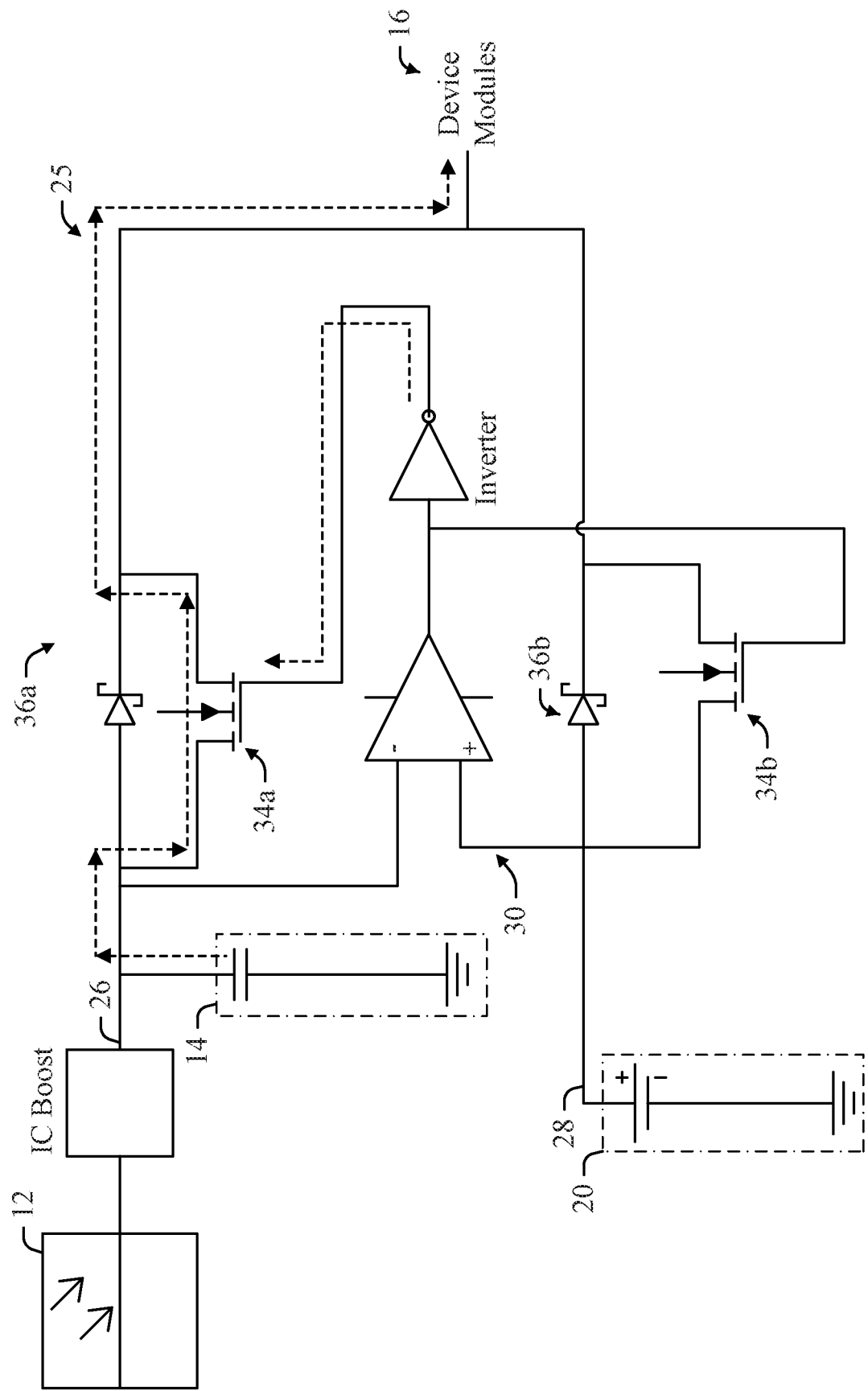


FIG. 2B

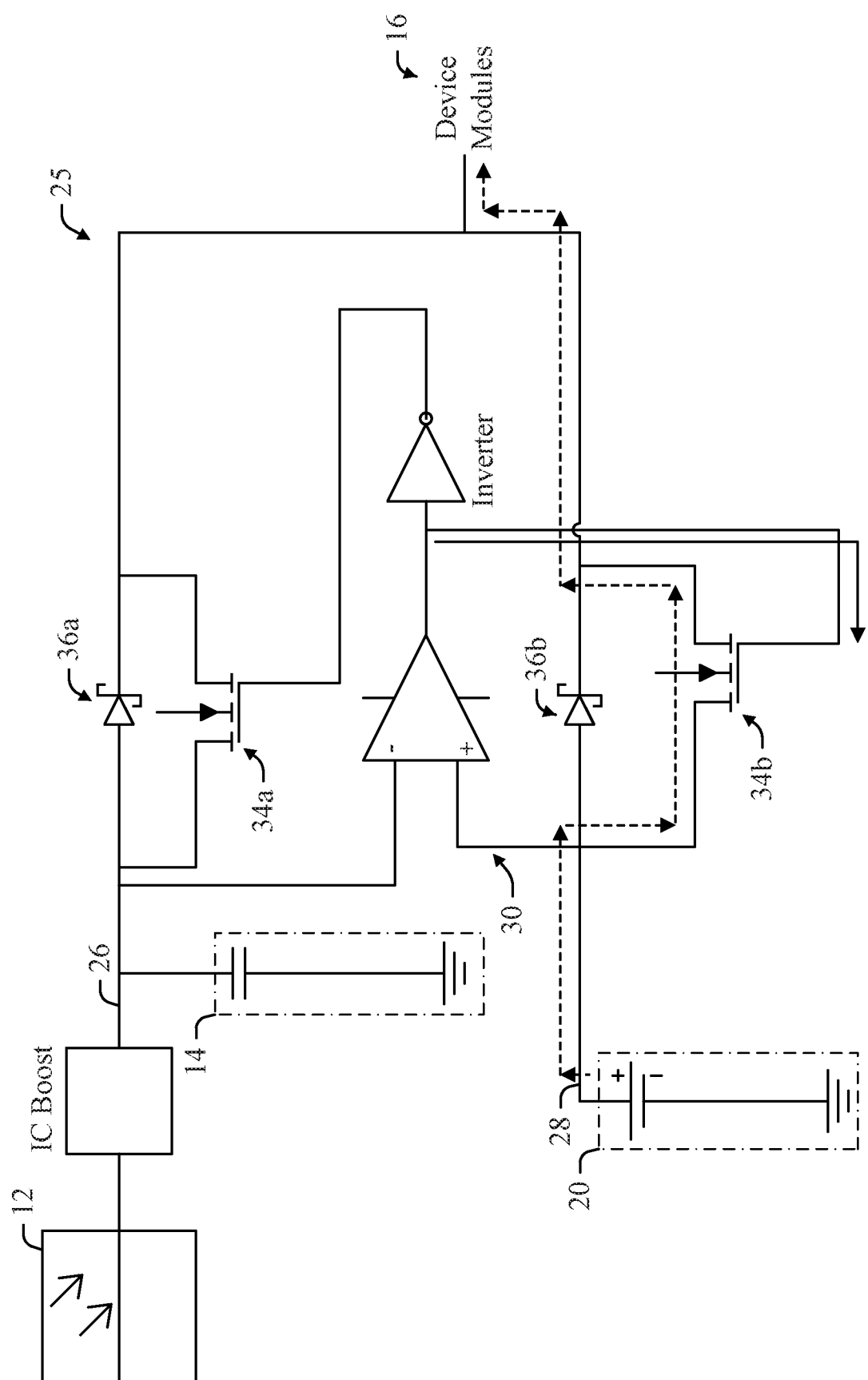


FIG. 2C

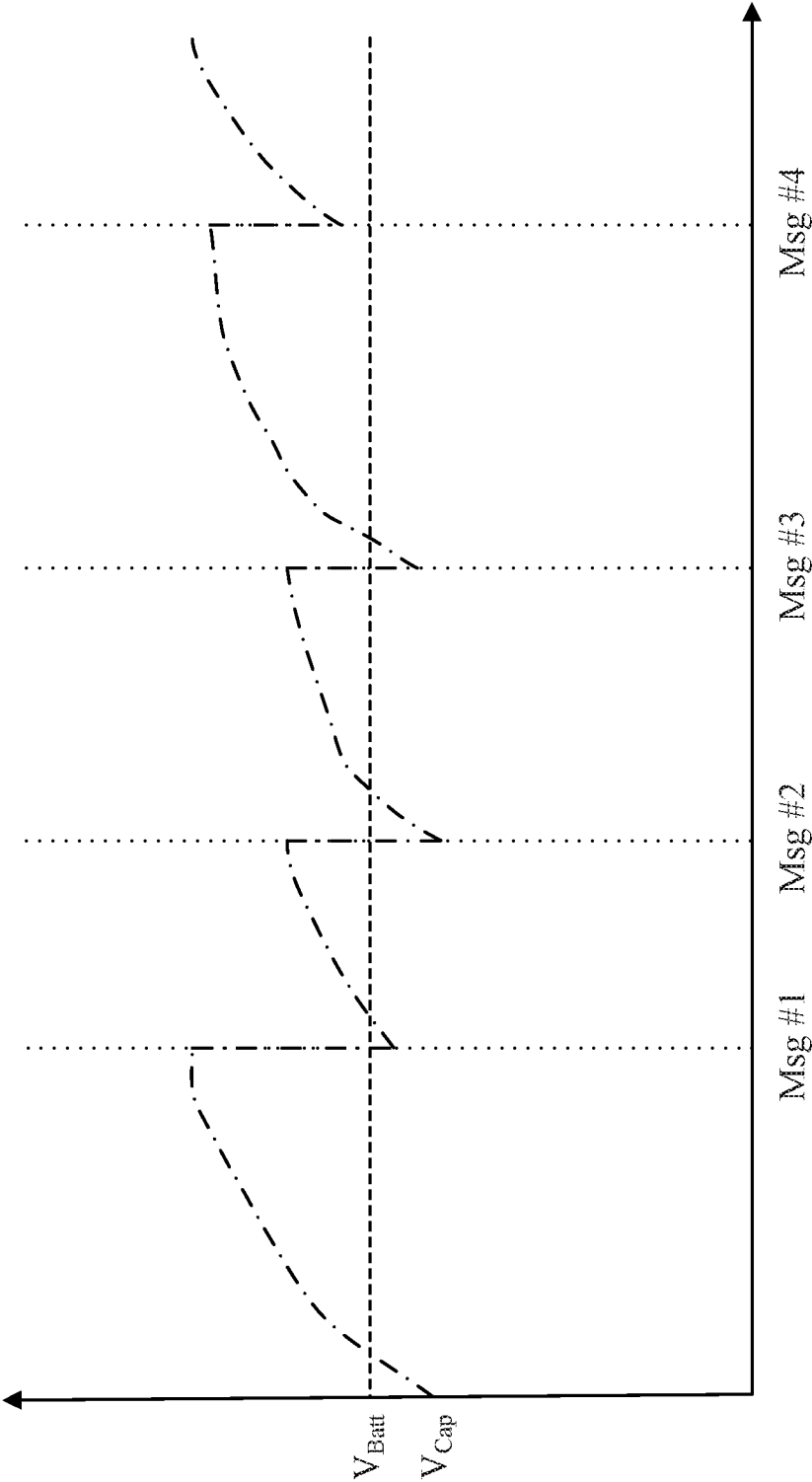


FIG. 3

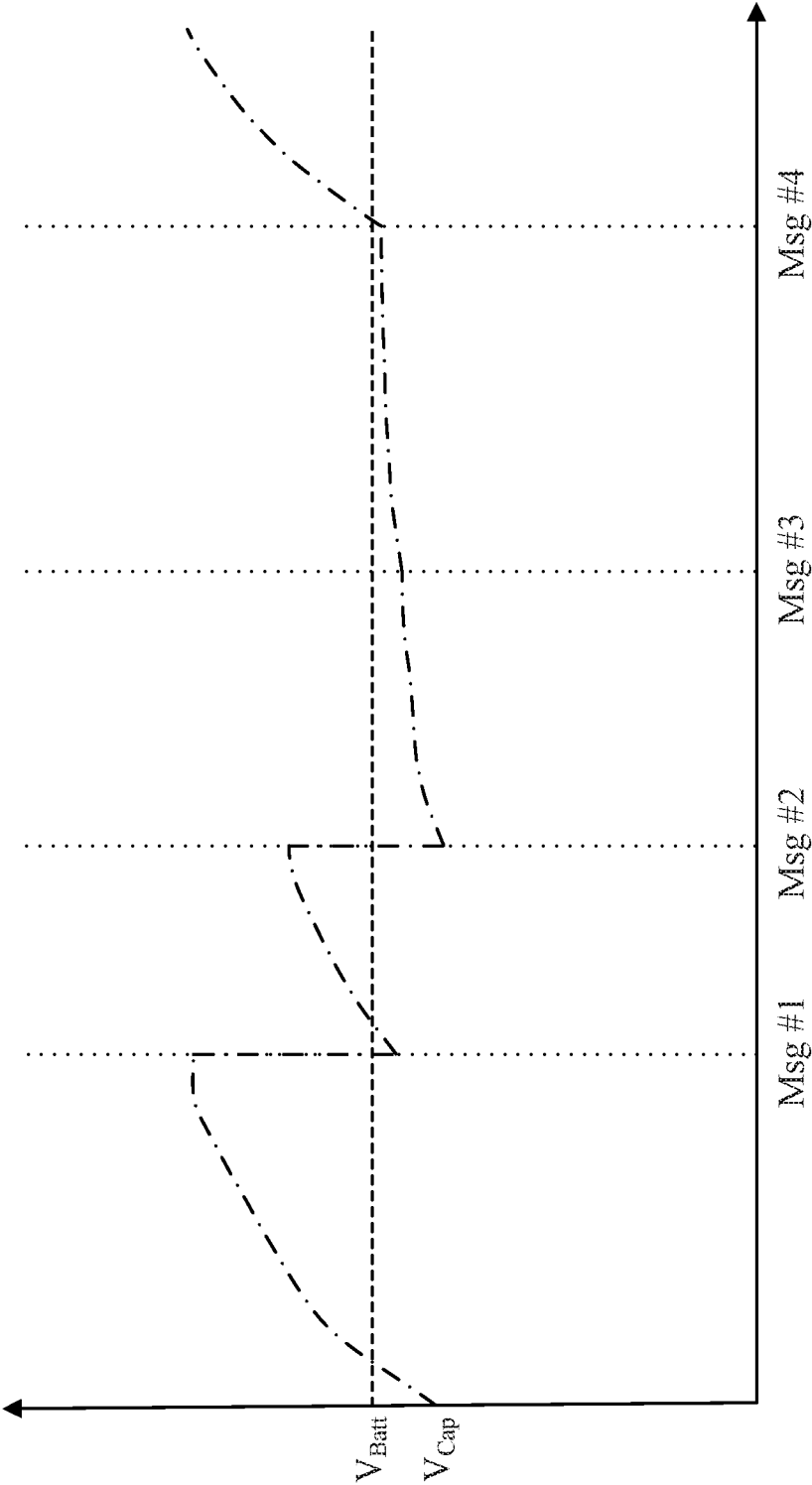


FIG. 4

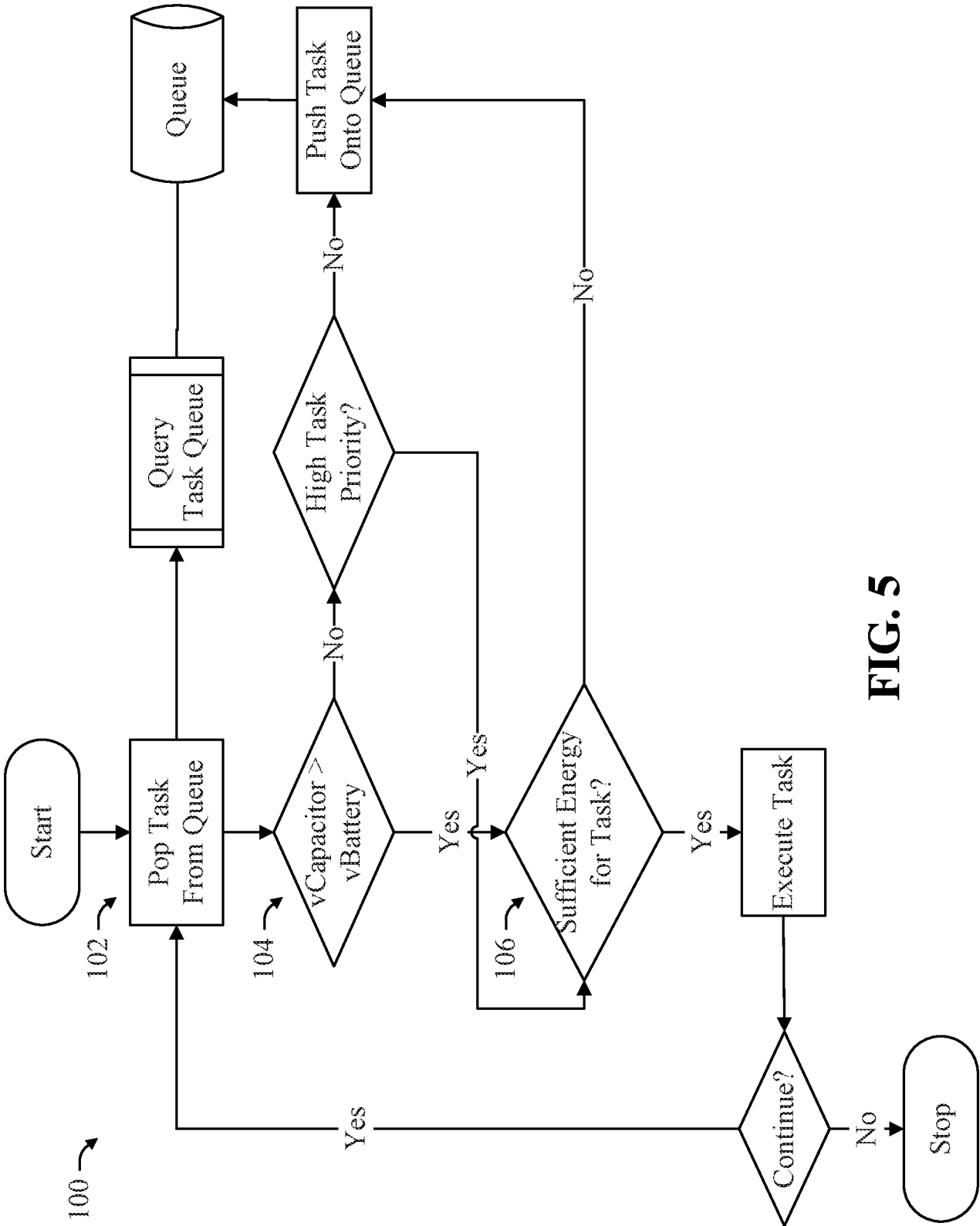


FIG. 5

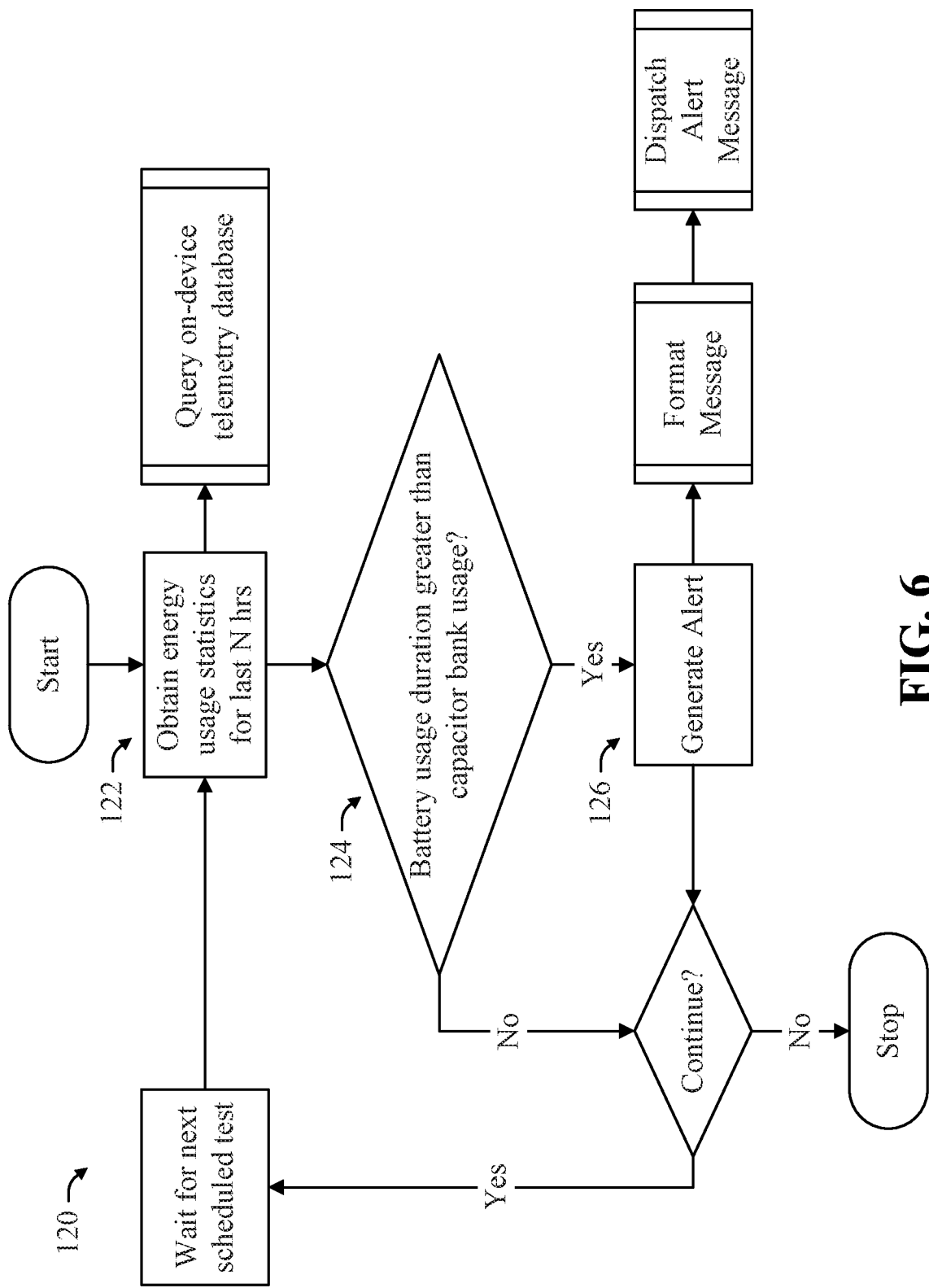
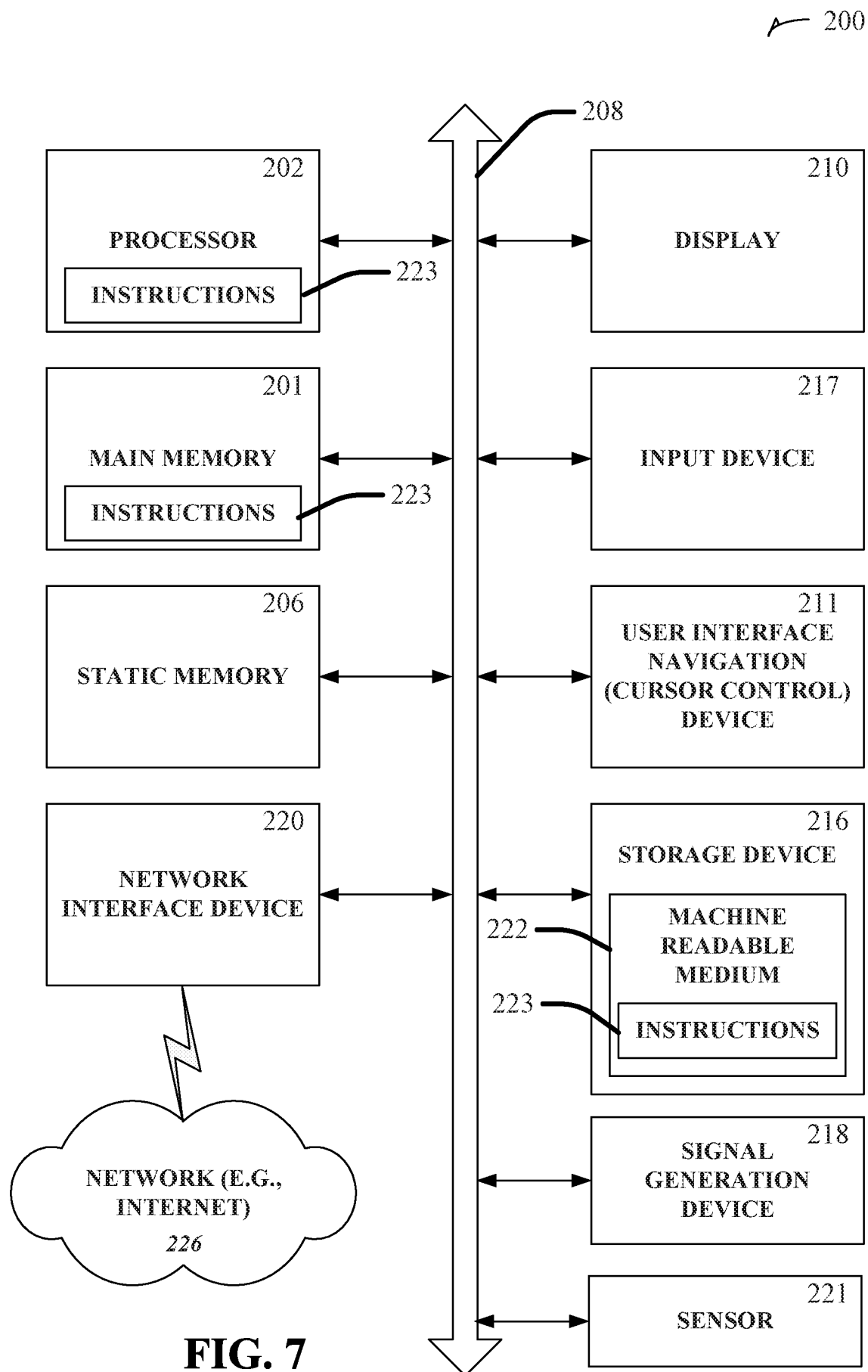


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/060620**A. CLASSIFICATION OF SUBJECT MATTER****H02J 7/00(2006.01)i, H02J 7/34(2006.01)i, H04L 12/28(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H02J 7/00; G06K 7/00; H02J 7/35; G01R 21/133; H02J 3/06; H02J 7/34; H04L 12/28

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & keywords: energy harvesting, supercapacitor, battery, charging, discharging, IoT device

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0068669 A1 (JOHN T. TRAINOR et al.) 22 March 2012	1-5, 14-15, 18-19, 21
Y	See paragraphs [0015]-[0016], [0031]-[0047], [0058]-[0060]; and figure 3.	, 24-25 6-13, 16-17, 20 , 22-23
Y	US 2011-0309145 A1 (NEIL RICHARDSON et al.) 22 December 2011	6-13, 20
	See paragraphs [0067]; claims 10, 14; and figures 10-13.	
Y	US 2004-0232878 A1 (PHILIP R. COUCH et al.) 25 November 2004	16-17, 22-23
	See paragraphs [0021]-[0032]; claim 10; and figure 1.	
A	US 2014-0103855 A1 (JAMES F. WOLTER) 17 April 2014	1-25
	See paragraphs [0027]-[0033]; and figures 1-6.	
A	US 2010-0039062 A1 (GONG-EN GU et al.) 18 February 2010	1-25
	See paragraphs [0022]-[0029]; and figure 1.	



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

20 February 2017 (20.02.2017)

Date of mailing of the international search report

20 February 2017 (20.02.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

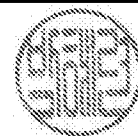
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea

Facsimile No. +82-42-481-8578

Authorized officer

PARK, Hye Lyun

Telephone No. +82-42-481-3463



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2016/060620

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2012-0068669 A1	22/03/2012	EP 1994623 A2 US 2007-0182362 A1 US 2010-0315046 A1 US 7692411 B2 US 7982439 B2 WO 2007-082168 A2 WO 2007-082168 A3	26/11/2008 09/08/2007 16/12/2010 06/04/2010 19/07/2011 19/07/2007 22/11/2007
US 2011-0309145 A1	22/12/2011	CN 102426474 A CN 102426474 B EP 2397965 A2 EP 2397965 A3 EP 2397965 B1 US 8333323 B2	25/04/2012 16/12/2015 21/12/2011 01/02/2012 11/09/2013 18/12/2012
US 2004-0232878 A1	25/11/2004	US 6914411 B2	05/07/2005
US 2014-0103855 A1	17/04/2014	US 2015-0008864 A2 US 2016-0020728 A1 US 9136732 B2	08/01/2015 21/01/2016 15/09/2015
US 2010-0039062 A1	18/02/2010	None	