

(51) International Patent Classification:
H02J 9/00 (2006.01)(21) International Application Number:
PCT/US2016/037846(22) International Filing Date:
16 June 2016 (16.06.2016)

(25) Filing Language: English

(26) Publication Language: English

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Princeton, New Jersey 08540 (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, 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, 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).

(54) Title: METHOD AND APPARATUS FOR DECREASING POWER CONSUMPTION IN A LOW POWER DEVICE

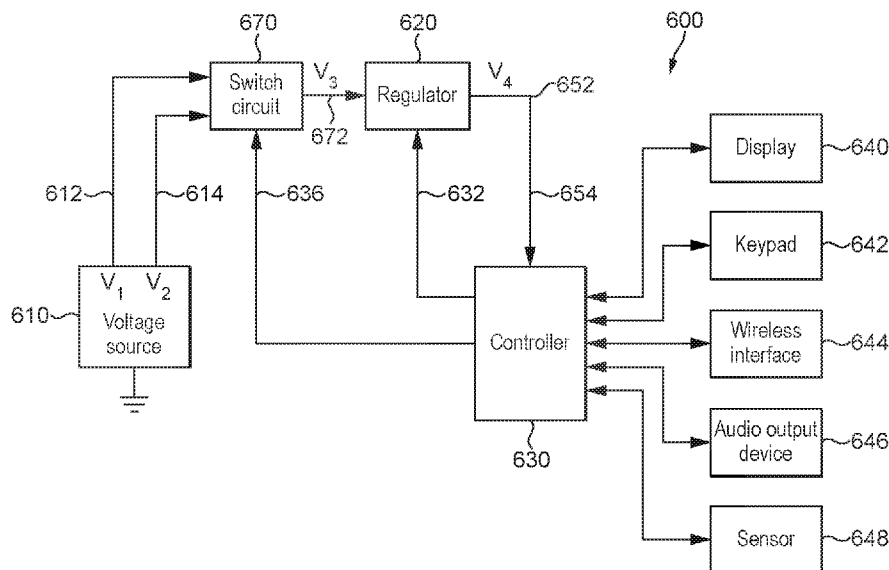


FIG. 6

(57) **Abstract:** Efficient techniques are provided for decreasing energy consumption in a low power device. An apparatus includes a voltage source (610) including a first voltage output (612) at a first voltage level and a second voltage output (614) at a second voltage level, a switch circuit (670) coupled to the voltage source that alternately selects one of the first voltage level and the second voltage level to output a third voltage level responsive to a first control signal (636) and a regulator (620) coupled to the first voltage output that outputs a fourth voltage level responsive to a second control signal (632). A method includes providing (1410) a first and a second voltage, alternately selecting (1420) one of the first voltage and the second voltage to output a third voltage responsive to a first control and regulating (1430) the third voltage to provide a fourth voltage responsive to a second control.

Published:

— *with international search report (Art. 21(3))*

METHOD AND APPARATUS FOR DECREASING POWER CONSUMPTION IN A LOW POWER DEVICE

5 TECHNICAL FIELD

[0001] The present disclosure relates to low power electronic devices and more specifically to decreasing power consumption in a low power device.

BACKGROUND

- 10 [0002] Any background information described herein is intended to introduce the reader to various aspects of art, which may be related to the present embodiments that are described below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light.
- 15 [0003] Unlike analog home and office networks of the past, today's digital home and office networks can distribute audio, video and data from one device to another, and can also support interactive dialogues between devices or between a device and the Internet. In particular, the advancement of low cost short range wireless communications has allowed many services to evolve and new services to be created within the home and office environment. Nearly every
- 20 aspect of the home has become connected — from the living room to the kitchen to the garage. The traditional PC, mobile and CE domains are coming together and creating a melting pot of new interactive applications and interactive appliances blurring the boundaries of these traditional domains. For the consumer, service operators and device vendors, this evolution offers a continuous flow of new compelling applications, use cases and business opportunities
- 25 which would be unthinkable in the past. Connected homes have smart appliances, connected lights, streaming media players and much more. The home space for connected accessories is rapidly growing. Thermostats, cameras, door locks, security or alert sensors, scales, kitchen appliances, TV's, stereo's, lighting, and even toothbrushes are all connected, meaning the 'home of the future' is becoming a reality.
- 30 [0004] Connectivity from the service operators or providers to the home and office environment may be accomplished via at least one medium, including cable/fiber, circuit switched or landline

telephone also known as Public Switched Telephone Network (PSTN), cellular or mobile telephone, satellite, over the air terrestrial broadcast, wireless cable over microwave (e.g., Multichannel Multipoint Distribution Services), other wireless networks, etc. Some networks like cable, circuit switched telephone (e.g., using Digital Subscriber Line, DSL or xDSL, technology) and cellular or mobile telephone networks permit full connectivity through duplex communication channels, including downstream and upstream channels. Downstream channels are used to transmit signals from the server, or service provider to the user or subscriber. Upstream channels are used to transmit signals from the user to the server. Satellite, over the air terrestrial broadcast and wireless cable service providers cannot provide duplex communication through their respective mediums and generally combine their downstream systems with upstream channels or services of other service providers (e.g., circuit switched telephone, cellular telephone) to accomplish full connectivity to the home and office environment.

[0005] The connectivity to the home or office environments may include video, voice, audio and/or data. The data connectivity may include internet access. Nowadays, modems, such as cable modems, offer Internet and general data connectivity to subscribers' homes. These modems are typically connected to an information distribution network, such as a coaxial cable network, an optical fiber network, a hybrid fiber/coaxial cable network, or a wireless network, and communicate with a network device outside the home (e.g., a termination system, such as a cable modem termination server (CMTS)). Within the home, the modem may be connected to an in-home network, such as an Ethernet network, an in-home coaxial cable network (e.g., per the Multimedia over Coax Alliance (MoCA) specification), wireless network, etc., and various devices within the home may use that network to ultimately communicate with network devices outside the home. Additionally, the modem may provide telephone services to the home (e.g., Voice over IP (VoIP) services) and various other services, e.g., home security, home temperature control or thermostat, home fire alarm, home appliance control, home energy control (e.g., lighting), etc. Such multi-function modems are commonly referred to as a gateway or gateway device.

[0006] The connectivity within the home and office networks may also be performed through a number of low power short range wireless devices generally operated by batteries. These devices generally communicate via wireless sensor networks supporting e.g., the Institute of Electrical and Electronics Engineers (IEEE) standard 802.15.4 and Zigbee Alliance standard.

[0007] FIG. 1 illustrates a block diagram of a prior art low power device 100 which is used as low power device 540 of a prior art home security system similar to home security/alert system 500. Low power device 100 includes battery pack 110 coupled to buck regulator 120. Battery pack 110 includes four batteries (510A-D) connected in series. The batteries are each 1.5 Volt (V) batteries, producing a 6V voltage source for the battery pack. Buck regulator 120 is a Direct Current (DC)-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). Buck regulator 120 is coupled to controller or processor 130 and down-converts the 6V voltage input to 2.7V, as required by controller 130 and other loads. A 6V battery pack is used (instead of 3V or 4.5V) for a long operation of the device before batteries need to be replaced. Controller 130 provides one or more control signals 132 that control the operation of buck regulator 120. Controller 130 also provides control signals and communicates with functional components of the low power device 100 associated with its main functionality, for example, display 140, keypad 142, wireless interface 144 and audio output device 146.

[0008] In low power device 100, controller 130 operates in two modes; normal mode and sleep mode. The device remains in sleep mode for a large percentage of time, generally greater than 90 percent. In sleep mode, the current draw required at the output of buck regulator 120 is very low (e.g., 1-2 micro amps, μA). However, buck regulator 120 may consume 10 μA itself, which is undesirable when in sleep mode, unnecessarily decreasing battery life.

[0009] Short battery life is not only inconvenient but also fatal to the commercial success of these multi-year low power electronics devices due to the complexity and cost of replacing batteries.

[0010] Therefore, there is a need to provide efficient techniques for improving the operational life of low power sources, e.g., battery sources. In general, it is of interest to decrease energy or power consumption in low power devices. The present disclosure is directed towards such a technique.

SUMMARY

[0011] According to an aspect of the present disclosure, an apparatus is provided, the apparatus including a voltage source including a first voltage output at a first voltage level and a second voltage output at a second voltage level, a switch circuit coupled to the voltage source that

alternately selects one of the first voltage level and the second voltage level to output a third voltage level responsive to a first control signal and a regulator coupled to the switch circuit responsive to a second control signal that outputs a fourth voltage level.

[0012] According to another aspect of the present disclosure, a method is provided, the method including providing a first voltage output and a second voltage, alternately selecting one of the first voltage and the second voltage to output a third voltage responsive to a first control signal and regulating in a regulator the third voltage responsive to a second control signal to output a fourth voltage.

[0013] Additional features and advantages of the present disclosure will be made apparent from the following detailed description of illustrative embodiments which proceeds with reference to the accompanying figures.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The present disclosure may be better understood in accordance with the following exemplary figures briefly described below:

FIG. 1 Illustrates a block diagram of a prior art low power device;

FIG. 2 illustrates a block diagram of an exemplary arrangement for a networking communication system in accordance with an embodiment of the present disclosure;

FIG. 3 illustrates a block diagram of an exemplary gateway system in accordance with an embodiment of the present disclosure;

FIG. 4 illustrates a block diagram of an exemplary gateway device in accordance with an embodiment of the present disclosure;

FIG. 5 illustrates a simplified block diagram of a home security/alert system in accordance with an embodiment of the present disclosure;

FIG. 6 illustrates a block diagram of a low power device used in a home security/alert system in accordance with an embodiment of the present disclosure;

FIG. 7A illustrates a simplified schematic for a regulator in accordance with an embodiment of the present disclosure;

FIG. 7B illustrates the behavior of control signals for a regulator as a function of time in accordance with an embodiment of the present disclosure;

FIG. 7C illustrates the behavior of control signals for a regulator as a function of time in accordance with an embodiment of the present disclosure;

FIG. 8 illustrates a voltage source in accordance with one embodiment of the present disclosure;

FIG. 9 illustrates a block diagram of a switch circuit in accordance with an embodiment of the present disclosure;

FIG. 10 illustrates the behavior of control signals for a regulator and a switch circuit as a function of time in accordance with an embodiment of the present disclosure;

FIG. 11 illustrates a block diagram of a low power device used in a home security/alert system in accordance with an embodiment of the present disclosure;

FIG. 12A illustrates a coupling circuit in accordance with one embodiment of the present disclosure;

FIG. 12B illustrates the behavior of control signals for a coupling circuit as a function of time in accordance with one embodiment of the present disclosure;

FIG. 12C illustrates a coupling circuit in accordance with one embodiment of the present disclosure;

FIG. 13 illustrates a regulator coupled to a coupling circuit in accordance with one embodiment of the present disclosure; and

FIG. 14 illustrates a flowchart of an exemplary method in accordance to one embodiment of the present disclosure.

DETAILED DISCUSSION OF THE EMBODIMENTS

[0015] It should be understood that the elements shown in the figures may be implemented in various forms of hardware, software or combinations thereof. Preferably, these elements are implemented in a combination of hardware and software on one or more appropriately programmed general-purpose devices, which may include a processor, memory and input/output interfaces. Herein, the phrase "coupled" is defined to mean directly connected to or indirectly connected with through one or more intermediate components. Such intermediate components may include both hardware and software based components.

[0016] The present description illustrates the principles of the present disclosure. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although

not explicitly described or shown herein, embody the principles of the disclosure and are included within its scope.

[0017] All examples and conditional language recited herein are intended for educational purposes to aid the reader in understanding the principles of the disclosure and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions.

[0018] Moreover, all statements herein reciting principles, aspects, and embodiments of the disclosure, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

[0019] Thus, for example, it will be appreciated by those skilled in the art that the block diagrams presented herein represent conceptual views of illustrative circuitry embodying the principles of the disclosure. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudocode, and the like represent various processes which may be substantially represented in computer readable media and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0020] The functions of the various elements shown in the figures may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term “processor” or “controller” should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, read only memory (ROM) for storing software, random access memory (RAM), and nonvolatile storage.

[0021] Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the figures are conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0022] In the claims hereof, any element expressed as a means for performing a specified function is intended to encompass any way of performing that function including, for example, a) a combination of circuit elements that performs that function or b) software in any form, including, therefore, firmware, microcode or the like, combined with appropriate circuitry for
5 executing that software to perform the function. The disclosure as defined by such claims resides in the fact that the functionalities provided by the various recited means are combined and brought together in the manner which the claims call for. It is thus regarded that any means that can provide those functionalities are equivalent to those shown herein.

[0023] The present disclosure is directed to efficient techniques for decreasing energy or power
10 consumption in a low power device. It includes improving the operational life of low power sources, e.g., battery sources, used in a number of low power short range wireless devices within the home or office environment. These devices generally communicate via wireless sensor networks supporting e.g., the Institute of Electrical and Electronics Engineers (IEEE) standard 802.15.4 and Zigbee Alliance standard. Short battery life is fatal to the commercial success of
15 these multi-year low power electronics devices due to the complexity and cost of replacing batteries.

[0024] Battery operated devices include remote controls, key fobs or general keyless entry, starter or opener devices (e.g., garage door opener, car starter, etc.), and other similar devices. A set of these devices are used for home control or home security devices, and often include
20 keypads, audible indicators or alarms, sensors, cameras, and other functions. Customer requirements may include a requirement for minimum operational life before the batteries have to be changed or replaced. In addition, some of these devices may include the requirement to automatically and periodically communicate (wirelessly) with other devices. For example, a security/alert tablet that is the main control center for a home security/alert system may have to
25 wirelessly communicate every 2 to 6 seconds with a remote keypad, window sensor or door sensor, for some type of handshake, a requirement not typically found on previous devices (e.g., wired remote keypads which are powered through the connecting wires). Achieving long operational life from a battery or set of batteries can be a challenge when faced with this new requirement.

[0025] Remote control devices have been shown to operate with battery life of greater than five
30 years. However, they do not usually include a requirement for periodic wireless communication.

The present disclosure addresses these issues by providing a dual mode operational configuration for the battery connection.

[0026] Turning to FIG. 2, a block diagram of a typical arrangement for a networking communication system 200 according to aspects of the present disclosure is shown. According to an exemplary embodiment, gateway 201 is an advanced cable gateway, cable modem, DSL (Digital Subscriber Line) modem or the like, and is coupled to a wide area network (WAN) link 225 through a WAN interface to service provider 210. The WAN link 225 may be any one or more of the possible communication links including, but not limited to, coaxial cable, fiber optic cable, telephone line, or over the air links. The gateway 201 is also coupled via a local area network (LAN) interface to home network 250 which couples one or more customer premises equipment (CPE) devices 280A-N. The home network 250 preferably includes a wireless link but may also include wired links such as co-axial cable or Ethernet. CPE devices 280A-N may include, for example, personal computers, network printers, digital set-top boxes, and/or audio/visual media servers and players, among others.

[0027] Service provider 210 provides one or more services, such as voice, data, video and/or various advanced services, over WAN link 225 to CPE devices 280A-N through gateway 201 and home network 250. Service provider 210 may include Internet related services and server structures such as a Dynamic Host Configuration Protocol (DHCP) server 211 and Domain Name System (DNS) server 212, and may include other servers and services as well (e.g., video on demand, news, weather). It is important to note that these servers and services can be co-located or widely distributed, physically and/or virtually, in both hardware and software. It is contemplated that service provider 210 operates in a conventional manner in accordance with well-known protocols (e.g., Data Over Cable Service Interface Specification, DOCSIS). In an illustrative cable application, service provider 210 may be, for example, a cable multiple service operator (MSO).

[0028] Gateway 201 acts as the interface between the WAN link 225 external to the customer's home and the home network 250 located in the customer's home. Gateway 201 converts transport data packets, such as packets in an IP protocol, from a format used in the WAN to a format used in the home network or LAN. Gateway 201 also routes data packets, including the converted data packets between the WAN and one or more devices on the home network. Gateway 201 may include interfaces for both wired networking (e.g., Ethernet MoCA) and

wireless networking. Gateway 201 allows data, voice, video and audio communication between the WAN and CPE devices 280A-N used in the customer's home, such as analog telephones, televisions, computers, and the like.

[0029] It is important to note that in some configurations, the gateway 201 may be partitioned into two separate devices coupled together in some communicative manner. The first device, connected to the WAN portion of the system, may be referred to as a cable modem or network termination device (NTD). The second device, connected to the home LAN portion of the system, may be referred to as a home router, a home server, or a home gateway. Functionally, and as will be described below, the two devices operate in a manner consistent with gateway 201.

[0030] FIG. 3, shows a gateway system 300 according to aspects of the present disclosure. Gateway system 300 operates in a manner similar to networking communication system 200 described in FIG. 2. In gateway system 300, network 301 is coupled to gateway 302, which is similar to gateway 201. Gateway 302 connects to a wired phone 303. Gateway 302 also connects to computer 305 by wired means, e.g., Ethernet cable. In addition, gateway 302 interfaces with devices 304A-304C through a wireless interface using one or more antennas 306. Gateway 302 may also connect to devices 304A-304C by wired means, e.g., Ethernet cable. Gateway 302 may also interface with computer 305 using the one or more antennas 306. Devices 304A-304C may be consumer electronics devices, e.g., a television, a set-top box, a clock radio, a Compact Disk (CD) player, DVD player, a Videocassette Recorder (VCR), a Digital Video Recorder (DVR), refrigerator, washing machine, dishwasher, etc. Devices 304A-304C may also be control devices for various services, e.g., home security, home temperature control or thermostat, home fire alarm, home appliance control, home energy control (e.g., lighting), etc. Devices 304A-C may also connect (wirelessly or not) to yet other devices, 304A1, 304A2, 304B1, that are necessary for the particular service that they provide, e.g., keypads, sensors, cameras, remote controls.

[0031] In particular, gateway system 300 operates as part of a cable network interface and acts to interface a packet data cable system to one or more home networks. Gateway system 300 includes gateway 302 that provides the interface between the network 301, operating as a WAN, and the home network(s). Gateway system 300 also includes wired analog telephone device 303 capable of operating as a home telephone when connected through gateway 302. In addition,

gateway 302 also acts to provide a radio frequency (RF) interface to multiple wireless devices 304A, 304B, and 304C. Wireless devices 304A, 304B and 304C may be handheld devices that operate using wireless packet transmissions via one or more antennas 306 on gateway 302. Wireless devices 304A, 304B and 304C may also be devices that are not handheld and that are
5 mounted on walls or placed in different rooms of the home (not shown). For example, it is commonplace to mount a control device for a home security system on a wall. In other embodiments, other devices with wireless interfaces including, but not limited to routers, tablets, set-top boxes, televisions, media players and home appliances may be used.

[0032] The wireless interface included in gateway 302 may also accommodate one or more
10 wireless formats including Wi-Fi, Institute of Electrical and Electronics Engineers standard IEEE 802.11 or other similar wireless communication protocols. Further, it is important to note that each antenna in the system may be attached to a separate transceiver circuit. As shown in FIG. 3, gateway 302 includes two transceiver circuits and two antennas. Device 304A and computer 305 also include two transceiver circuits and two antennas while device 304B and device 304C
15 include only one transmit / receive circuit and one antenna. In some alternate designs it may be possible that more than one antenna may be included with, and used by, a single transceiver circuit.

[0033] In operation, gateway 302 may provide Internet protocol (IP) services (e.g., data, voice, video, and/or audio) between devices 304A-C and Internet destinations identified and connected
20 via network 301. Gateway 302 may also provide IP voice services between wired phone 303 and call destinations routed through network 301. Gateway 302 may also provide other services between service provider (e.g., 200) and control devices 304A-304C for the services, e.g., home security, home temperature control or thermostat, home fire alarm, home appliance control, home energy control, etc. Gateway 302 may further provide connectivity to a local computer
25 305 either via a wired connection such as is shown in FIG. 3 or via a wireless connection through one or more antennas and transceiver circuits. Thus, example interfaces for computer 305 include Ethernet and IEEE 802.11. As noted above, gateway 302 may physically be configured as two components, a cable modem or NTD that connects to network 301 and a home gateway that connects to all other devices in the home.

[0034] Gateway 302 further includes a communication front end circuit for interfacing with the
30 headend or CMTS through the network 301. In some embodiments, the gateway 302 further

includes circuitry for communicating in the home network or LAN using MoCA protocols over a co-axial cable. The communication front end circuit may include a diplexer filter, or a triplexer filter if MoCA is included, for separating the upstream communication and downstream communication signals (as well as MoCA signals if present).

5 [0035] Turning to FIG. 4, a block diagram of an exemplary gateway device 400 according to aspects of the present disclosure is shown. Gateway device 400 may be similar to gateway 302 described in FIG. 3 or to gateway 201 described in FIG. 2. In gateway device 400, an input signal is provided to RF input 401. RF input 401 connects to tuner 402. Tuner 402 connects to central processor unit 404. Central processor unit (CPU) 404 connects to phone D/A (digital to
10 analog) interface 406, transceiver 408, transceiver 409, Ethernet interface 410, system memory 412, and user control 414. Transceiver 408 further connects to antenna 420. Transceiver 409 further connects to antenna 421. It is important to note that several components and interconnections necessary for complete operation of gateway device 400 are not shown in the interest of conciseness, as the components not shown are well known to those skilled in the art.
15 Gateway device 400 may be capable of operating as an interface to a cable communication network, to a DSL network and to over the air networks, e.g., cellular telephone, satellite, etc., and further may be capable of providing an interface to one or more devices connected through either a wired and wireless home network.

[0036] A signal, such as a cable signal on the WAN, is interfaced to tuner 402 through RF input
20 401. Tuner 402 performs RF modulation functions on a signal provided to the WAN and demodulation functions on a signal received from the WAN. The RF modulation and demodulation functions are the same as those commonly used in communication systems, such as cable systems. Central processor unit 404 accepts the demodulated cable signals and digitally processes the signal from tuner 402 to provide voice signals and data for the interfaces in
25 gateway 400. Similarly, central processor unit 404 also processes and directs any voice signals and data received from any of the interfaces in gateway 400 for delivery to tuner 402 and transmission to the WAN.

[0037] System memory 412 supports the processing and IP functions in central processor unit 404 and also serves as storage for program and data information. A portion of system memory
30 412 is a non-transitory computer readable medium having stored thereon instructions of program code for executing methods when the program code is executed on a computer. Processed and/or

stored digital data from central processor unit 404 is available for transfer to and from Ethernet interface 410. Ethernet interface may support a typical Registered Jack type RJ-45 physical interface connector or other standard interface connector and allow connection to an external local computer. Processed and/or stored digital data from central processor unit 404 is also
5 available for digital to analog conversion in interface 406. Interface 406 allows connection to an analog telephone handset. Typically, this physical connection is provided via an RJ-11 standard interface, but other interface standards may be used. Processed and/or stored digital data from central processor unit 404 is additionally available for exchange with transceiver 408 and transceiver 409. Transceiver 408 and transceiver 409 can both support multiple operations and
10 networked devices simultaneously. Central processor unit 404 is also operative or configured to receive and process user input signals provided via a user control interface 414, which may include a display and/or a user input device such as a hand-held remote control and/or other type of user input device.

[0038] As noted above, the gateway device 400 may be configured to operate as an NTD. In this
15 case, central processing unit 404 may only connect to tuner 402, Ethernet interface 410, and system memory 412. Phone D/A interface 406, transceiver 408 and/or transceiver 409 may not be present or used. Further, an NTD may not include a direct user interface and as such may not include user control 414. Additionally, the NTD may include and support more than one Ethernet interface 410 and may be capable operating each Ethernet interface as a separate virtual
20 circuit between the content service provider(s) and the home gateway attached to the Ethernet interface, thus allowing the creation of separate LANs for each content consumer.

[0039] FIG. 5 illustrates a simplified block diagram 500 of a home security/alert system according to aspects of the present disclosure. The service is provided by service provider 510 similar to service provider 200 and coupled to gateway 520 similar to gateway 201 and 302. The
25 security/alert system includes security/alert control device 530 coupled to gateway 520 and implemented in a home or office, similarly to any of CPE devices 280A-N or devices 304A-C. Security control device 530 may be implemented using a computing system including a processor, at least one input/output interface, at least one memory (e.g., Random Access Memory, RAM) and/or storage devices (e.g., Hard Disk Drive, HDD). Security control device
30 530 may be implemented on, but is not limited to, desktop computers, cellular phones, smart phones, phone watches, tablet computers, personal digital assistant (PDA), netbooks, laptop

computers, set-top boxes or general multimedia content receiver and/or transmitter devices. In addition, security control device 530 is coupled and communicates wirelessly to low power device 540, e.g., keypad, lock, window sensors, door sensors, motion sensors, shock sensors, video camera, etc. The wireless connection between security control device 530 and low power device 540 may be performed via wireless sensor networks supporting e.g., the Institute of Electrical and Electronics Engineers (IEEE) standard 802.15.4 and the Zigbee Alliance standard. Security control device 530 may regularly communicate with low power device 540 for a handshake, e.g., every 2 to 6 seconds. In addition, low power device 540 may sporadically send information to security control device 530.

[0040] A home security or alarm system generally includes three main components. The first component is a detection element that detects status changes or emergencies (e.g., the door is opened by an unauthorized party or the front window is broken). Detection components (e.g., low power device 540) include door and window contacts or sensors, Passive Infrared (PIR) motion detectors, glass break sensors (to detect sounds of glass breakage), shock sensors (to detect forces applied to walls, doors, roofs, etc.), environmental sensors (to detect presence of water and sudden temperature changes), smoke detectors, carbon monoxide detectors, etc.

[0041] The second component of the security or alert system is the security/alarm control device (e.g., security control device 530) that is the brain of the system. The security/alarm control device performs monitoring and carries out the decision function by processing the information it receives from various sensors (e.g., low power device 540) and responding accordingly. The security/alarm control device communicates emergencies and system maintenance information to a central station monitoring center run by the service provider. The security/alarm control device may also broadcast alerts to anyone who is directly associated with the premises. In the event of a triggered alarm, a trained dispatcher may contact the home owner or user to verify the emergency situation and if necessary, contact the police, fire station or emergency services like 911 on the home owner's or user's behalf.

[0042] The third component of the security or alert system is the annunciation or deterrent that announces that a system has been breached or needs attention at the source, e.g., sirens, bells or flashing lights (e.g., low power device 540). Alerting people who are currently away from the home perimeter is part of the monitoring or communication component.

[0043] A home security/alert system may also include keypads to arm and disarm the system, or to enter passwords for access to the premises (e.g., low power device 540). And a home security/alert system may also include panic buttons that send an immediate, discreet call for help upon the press of a button (e.g., low power device 540).

5 [0044] Customer requirements may dictate that low power device 100 or 540, get regular status updates or perform a regular handshake with the main “brain” control device 530 (usually a tablet or similar device) of the security/alert system (wirelessly using ZigBee or similar communication standard), e.g., every 2 to 6 seconds. The constant switching from sleep mode to normal mode implies that the buck regulator/converter 120 is constantly using battery energy.

10 The problem is worsened due to some losses and inefficiencies will occur as a result of the difference between battery voltage 110 and the desired voltage at control IC 130 and other elements 140-148. In addition, the buck regulator 120 may consume 10 μ A itself, which is not desirable when in sleep mode, unnecessarily decreasing battery life. It is therefore of interest to conserve battery power in order to increase the operational life of the low power device before a

15 user is required to exchange batteries. In general, it is of interest to keep energy consumption in a low power device as low as possible, be it a battery source or a rectified power source.

[0045] The present disclosure provides a circuit or apparatus that decreases the power demands or energy consumption of a low power device (e.g., device 540) by providing a dual mode operational configuration for the power (e.g., battery) connection. FIG. 6 illustrates a block

20 diagram of low power device 600 similar to low power device 540 of home security/alert system 500 in accordance to aspects the present disclosure. Low power device 600 includes voltage (or power) source 610, which includes a first voltage output and a second voltage output. First voltage output terminal 612 is at a first voltage level V1. Second voltage output terminal 614 is at a second voltage level V2. The first and second voltage output terminals may also be provided

25 by two independent voltage sources. First voltage output and second voltage output are coupled to switch circuit 670. Switch circuit 670 is coupled to regulator 620 and outputs a signal 672 at a third voltage level V3. At any time, third voltage level V3 is one of first voltage level V1 and second voltage level V2. Regulator 620 may be a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). Regulator 620

30 may be similar to buck regulator 120 and is coupled to controller 630. Regulator 620 may be any of the regulator circuits well-known by one of ordinary skill in the pertinent art. Controller or

processor 630 may be any of well-known integrated circuits (IC's) known by one of ordinary skill in the pertinent art. Controller 630 is coupled to regulator 620. Controller 630 provides one or more control signals 632 that control the operation of regulator 620. Controller 630 also provides one or more control signals 636 to switch circuit 670. Controller 630 further provides control signals and communicates with functional components of the low power device associated with its main functionality, for example, display 640, keypad 642, wireless interface 644, audio output device 646 and sensor 648, as are well-known by one of ordinary skill in the pertinent art. Some or all the functional components 640 to 648 may be present in the low power device 600, depending on its functionality.

[0046] FIG. 7A illustrates a simplified schematic for a buck regulator 700 according to aspects of the present disclosure. Buck regulator 700 includes input terminal 710 to be coupled to an external voltage source (not shown), e.g., voltage source 610, that provides a voltage level V_{in} to buck regulator 700, for example, 6V. Input terminal 710 is coupled to switch A 720. Switch A 720 is coupled to switch B 730 and to inductor 740. Switch A 720 is controlled by control signal S_a 722. Switch B 730 is controlled by control signal S_b 732. Inductor 740 is coupled to capacitor 750. Capacitor 750 is coupled to output terminal 760. Output terminal 750 is to be coupled to one or more output loads and provide a voltage level V_{out} that is a down-conversion of the voltage level V_{in} , for example, 2.7V required by the output loads (e.g., controller 630). In addition, Switch B 730 and capacitor 750 are also coupled to a reference level or ground.

[0047] Switches A 720 and B 730 may be implemented with Field Effect Transistors (FET) or other types of switches known by one of ordinary skill in the pertinent art. Switches A 720 and B 730 may be controlled by a controller similar to controller 630, via control signals S_a 722 and S_b 732, respectively, similar to control signals 632. The control signals S_a 722 and S_b 732 sent by the controller are Pulse Width Modulated (PWM) waveforms delivered to buck regulator 700 to open and close switches A 720 and B 730. PWM based controller holds the frequency constant and varies the pulse width of signals S_a and S_b to adjust the output voltage. The controller (e.g., controller 630) uses either voltage or current feedback in a control loop to regulate the output voltage V_{out} in response to load changes.

[0048] FIG. 7B illustrates exemplary plots 725 and 735 of switch drive control signals S_a 722 and S_b 732, respectively, according to one embodiment of the present disclosure, during normal mode of operation as a function of time. Non-overlapping switch drives A and B ensure that

only one switch is on at a time to avoid unwanted current “shoot through”. In Phase 1, Switch B 730 is open ($S_b = 0$), and Switch A 720 is closed ($S_a = 1$). The inductor 740 is coupled to V_{in} through input terminal 710, so current flows from V_{in} to the load. The current increases due to the positive voltage across the inductor 740. In Phase 2, Switch A 720 is open ($S_a = 0$) and Switch B 730 is closed ($S_b = 1$). The inductor 740 is coupled to ground, so current flows from ground to the load. The current decreases due to the negative voltage across the inductor 740, and energy stored in the inductor is discharged into the load. A simple relationship for buck regulator 700 or 620 and the controller (e.g., controller 630) is that the output voltage of the regulator is a function of the duty cycle for switches A and B, more specifically: $V_{in} * \text{duty cycle } (A/B) = V_{out}$.

[0049] In low power device 600, controller 630 operates in two modes; normal mode and sleep mode. During normal mode, operation of the control signals S_a 722 and S_b 732 that drive regulator 620 is as shown in FIG. 7B and previously explained. The same control signals and their behavior described in FIG. 7B may also apply to regulator 120 in low power device 100.

However, the device 600 remains in sleep mode for a large percentage of time, generally greater than 90 percent. In sleep mode, the current draw at the output of regulator 620 is very low (e.g., 1-2 micro amps, μA). FIG. 7C illustrates plots 726 and 736 of the behavior of control signals S_a 722 and S_b 732 throughout a cycle of normal and sleep mode as a function of time, according to one embodiment of the present disclosure. During sleep mode, control signal S_a 722 remains at “1”, meaning that switch A 720 of buck regulator 700 or 620 remains closed. Also, during sleep mode, control signal S_b 732 remains at “0”, meaning that switch B 730 of buck regulator 700 (or 620) remains open. The same control signals and their behavior described in FIG. 7C may also apply to regulator 120 in low power device 100. According to the present disclosure, the number and values of control signals S_a 722 and S_b 732 are exemplary and other numbers and values may be chosen without departing from the scope of the present disclosure. For example, in one embodiment, one control signal S_{ab} may include two bits, b_0 and b_1 , where $b_0 = S_a$ and $b_1 = S_b$.

[0050] In one embodiment, regulator 620 may down-convert the input voltage down to 2.7V, for example, as required by controller 630 and other loads (e.g., 640-648). It is to be understood that the present disclosure is not limited to the precise embodiment of a regulator described in Figs. 7A-C, and various changes and modifications can be effected therein by one of ordinary skill in the pertinent art without departing from the scope of the present disclosure. In one embodiment,

voltage source 610 may be a battery pack including a plurality of batteries coupled in series and/or parallel. In another embodiment, voltage source 610 may be a rectified power source utilizing rectification circuits known by one of ordinary skill in the pertinent art. Rectification is the conversion of alternating current (AC) to direct current (DC). In one embodiment, regulator
5 620 may be an AC-to-DC regulator, including a rectification circuit.

[0051] FIG. 8 illustrates an exemplary voltage (or power) source 860 similar to voltage source 610 in accordance with one embodiment of the present disclosure. Voltage source 860 consists of a battery pack including at least two sets of batteries, each set of batteries including a plurality of batteries connected in series, e.g., four batteries, 860A-D, split in two sets, with 860A and
10 860B connected in series, and 860C and 860D also connected in series. The batteries may each be, for example, 1.5 Volt (V) batteries, producing a 3V voltage source for each set of the battery pack. Voltage source 860 includes first voltage output terminal 862 similar to 612 and second voltage output terminal 864 similar to 614. The voltage level at second voltage output terminal 864 may be similar to the voltage level at first voltage output terminal 862 (e.g., 3V). Compared
15 to voltage source 110, voltage source 860 has two “parallel” sets of lower voltage than the serial battery pack of voltage source 110 (e.g., half the voltage). However, the two “parallel” sets of voltage source 860 are not connected in parallel.

[0052] FIG. 9 illustrates a switch circuit 900 similar to switch circuit 670 in accordance with one embodiment of the present disclosure. Switch circuit 900 selects one of input signal 912 and 914
20 to output at 972 responsive to control signal 936. Switch circuit 900 may be implemented, for example, using FET transistors.

[0053] In operation, switch circuit 670 of low power device 600 (e.g., switch circuit 900) alternately switches its output 672 between inputs 612 and 614, according to the control signal 636 from controller 630. By alternately selecting between the two inputs 612 and 614, the
25 operational life of voltage source 610, or similarly 860, improves. More generally, the energy consumption of low power device 600 will decrease. This is in contrast with two popular ways of connecting two sources: in series and in parallel. A series connection is presented in source 110, where four batteries of 1.5 V are connected in series. Since batteries do not discharge equally, one can say that the performance of batteries in series is a function of the worst one. If any
30 battery fails, the circuit is interrupted. A connection in parallel, as would be the case if the two sets in Fig. 8 were connected in parallel, is also not ideal for similar reasons. Two parallel

sources are often not matched in characteristics and thus paralleling them will not achieve the expected “doubling” of operational life of each one independently. If one source discharges faster than the other, their parallel connection creates a current from the higher charge source to the lower charge source, i.e., one source will charge the other, which is undesirable, since they
5 are supposed to charge the load.

[0054] According to the present disclosure, each of the two sources 612 and 614 (or equivalently, 862 and 864) discharges independently and does not negatively impact the operation of the other. In addition, since the two sources are alternately switched (or selected) while in operation, both sources will tend to discharge at a similar pace. This is an important
10 feature for low power device 600, since the power source (e.g., batteries) in this device is generally expected to last many years, e.g., 5 years. Since discharged batteries tend to leak if they remain connected to a circuit for long periods, it is desirable for all the battery sources to discharge at a similar pace, so that they are replaced at the same time. As a result, the configuration of low power device 600 does perform as close as possible to double the
15 operational life of each source as expected, compared to a parallel connection or serial connection of the sources, and the customer replaces them at the same time, without any leakage issues

[0055] In one embodiment, control signal 636 regularly switches between inputs 612 and 614. In one embodiment, control signal 636 regularly switches between the two inputs with a period of
20 time t_0 . In one embodiment, control signal 636 regularly switches responsive to control signal 632 that controls regulator 620.

[0056] In one embodiment, during operation, control signal Sv 636 may only switch from one input to the other at the beginning (or end) of a sleep mode and remain constant otherwise. As a result, switch circuit 670 selects each voltage source 612 or 614 for an entire cycle of normal and
25 sleep mode. In one embodiment, since sleep mode of operation is long lasting, during sleep mode of operation, control signal 636 may regularly switch from one input to the other, for example, with a time period t_1 .

[0057] In one embodiment, during operation, control signal Sv 636 may switch from one input to the other during normal mode of operation. FIG. 10 illustrates an exemplary embodiment of the
30 present disclosure, showing plots of the behavior 1050 of control signal Sv 636 being responsive or related to the behavior 1010 of control signal 632 (or more specifically, to control signals Sa

and Sb of regulator 700, similar to FIG. 7C). In FIG. 10, only control signal Sa 722 is shown, but it is to be understood that Sb 732 has an opposite behavior or inverse value of control signal Sa 732. In FIG. 10, control signal Sv 636 switches values between 0 and 1, which may imply selecting input 612 or 614, respectively. In FIG. 10, during normal mode of operation, control signal Sv 636 switches (e.g., 1060, 1065, 1070 and 1075) whenever control signal Sa 722 switches from a value of 1 to a value of 0, i.e., at the end of a pulse of control signal Sa 722 (e.g., 1020, 1025, 1030 and 1035, respectively). As a result, switch circuit 670 switches between power sources 612 and 614 on every pulse of control signal Sa 722. As previously explained in FIG. 7A and 7B, a pulse of control signal Sa 722 closes switch A 720 which charges regulator 600. Therefore, each separate charge of regulator 600 is performed by a separate source (612 or 614), and the two sources will tend to discharge at a similar pace during normal mode of operation.

[0058] In another example, control signal 636 may switch whenever control signal Sa 722 transitions from a value of 0 to a value of 1, i.e., at the beginning of a pulse of control signal Sa 722. According to the present disclosure, the values and transition points of control signal Sv 636 are exemplary and other values and transition points may be chosen without departing from the scope of the present disclosure. For example, there may be a delay of time d between the transition of control signal Sa 722 and the transition of control signal Sv 636.

[0059] As shown in FIG. 10, control signal Sv 636 switches to 0 on transition 1080, triggered by transition 1040 of control signal Sa 722. This transition does not result due a transition of control signal Sa 722 from 1 to 0, as in previous transitions. It instead results due to a switch to sleep mode, and the fact that, in the previous sleep mode, control signal Sv 636 was at 1. Sleep mode and normal mode transitions are easily detected due to the difference in current between the modes.

[0060] FIG. 11 illustrates another block diagram of low power device 1100 similar to low power device 540 of home security/alert system 500 in accordance to aspects the present disclosure. Low power device 1100 is also similar to low power device 600, except for the presence of coupling circuit 1150. Low power device 1100 includes voltage (or power) source 1110, which includes a first voltage output and a second voltage output. First voltage output terminal 1112 is at a first voltage level V1. Second voltage output terminal 1114 is at a second voltage level V2. The first and second voltage output terminals may also be provided by two independent voltage

sources. First voltage output and second voltage output are coupled to switch circuit 1170. Switch circuit 1170 is coupled to regulator 1120 and outputs a signal 1172 at a third voltage level V3. At any time, third voltage level V3 is one of first voltage level V1 and second voltage level V2. Regulator 1120 may be a DC-to-DC power converter which steps down voltage (while
5 stepping up current) from its input (supply) to its output (load). Regulator 1120 may be similar to buck regulator 120 and is coupled to coupling circuit 650. Regulator 1120 may be any of the regulator circuits well-known by one of ordinary skill in the pertinent art. Switch circuit output 1172 is also coupled to coupling circuit 1150. Coupling circuit 1150 is coupled to controller or processor 1130. Controller or processor 1130 may be any of well-known integrated circuits
10 (IC's) known by one of ordinary skill in the pertinent art. Controller 1130 is coupled to regulator 1120. Controller 1130 provides one or more control signals 1132 that control the operation of regulator 1120. Controller 1130 also provides one or more control signals 1136 to switch circuit 1170. In addition, controller 1130 provides one or more control signals 1134 to coupling circuit 650 as will be described below. Controller 1130 further provides control signals and
15 communicates with functional components of the low power device associated with its main functionality, for example, display 1140, keypad 1142, wireless interface 1144, audio output device 1146 and sensor 1148, as are well-known by one of ordinary skill in the pertinent art. Some or all the functional components 1140 to 1148 may be present in the low power device 600, depending on its functionality. It is to be understood that all blocks and signals in low
20 power device 1100 are similar to respective blocks and signals in low power device 600, except for controller 1100.

[0061] FIG. 12A illustrates a coupling circuit 1270 similar to coupling circuit 1150 in accordance with one embodiment of the present disclosure. Coupling circuit 1270 includes input terminal 1273 (similar to input terminal 658) coupled to resistor 1276. Resistor 1276 is coupled
25 to switch S 1277. Coupling circuit 1270 also includes input terminal 1272 (similar to input terminal 652) coupled to switch N 1278. Switches S 1277 and N 1278 are coupled together and to output terminal 1274 (similar to output terminal 654). Switches S 1277 and N 1278 are controlled by control signals 12772 and 12782, respectively

[0062] In operation, when applied to low power device 1100, coupling circuit 1270 couples its
30 output 1154 (or 1274) to regulator 1120 and controller 1130, and receives one or more control signals 1134 to control the behavior of switches S 1277 and N 1278 (e.g., control signals 12772

and 12782, respectively). According to the present disclosure, when controller 1130 enters normal mode of operation (e.g., as in Figs. 7B-C), control signal 12782 closes switch N 1278 and control signal 12772 simultaneously opens switch S 1277. In normal mode of operation, the highest voltage level V1 at terminal 1112 from voltage source 1110 is utilized, or similarly, terminal 862 of voltage source 860. For the example of a battery pack with two sets of 2 batteries in series of 1.5V each, regulator 1120 may down-convert the input voltage of 3V down to 2.7V, for example, as required by controller 1130 and other loads (e.g., 1140-1148). In normal mode of operation, the required current draw at the output of coupling circuit 1150 may be, for example, in the order of 0.1A.

[0063] On the other hand, when controller 1130 enters sleep mode of operation (e.g., as in FIG. 7C), control signal 12782 opens switch N 1278 and control signal 12772 simultaneously closes switch S 1277. In sleep mode of operation, regulator 1120 is bypassed. For the example of a battery pack with two sets of 2 batteries in series of 1.5V each, 3V are provided through a resistor R 876 to controller 1130 and other loads (e.g., 1140-1148). In sleep mode of operation, the required current draw at the output of coupling circuit 1150 may be, for example, in the order of 1 to 2 μ A and resistor R 1276 may be between 150 and 300 K Ω . Since regulator 1120 may itself draw current in the order of 10 μ A, by bypassing regulator 1120 in sleep mode, the operational life of voltage source 1110, or similarly 860, will improve. More generally, the energy consumption of low power device 1100 will decrease.

[0064] In one embodiment of coupling circuit 1270, resistor R 1276 may be removed. In one embodiment of coupling circuit 1270, resistor R 1276 may be replaced by a low-dropout (LDO) regulator. An LDO regulator is a DC linear voltage regulator that can regulate the output voltage even when the supply voltage is very close to the output voltage.

[0065] Fig 12B illustrates the plots 12785 and 12775 of the behavior of control signals Sn 12782 and Ss 12772, respectively, throughout a cycle of normal and sleep mode as a function of time. During normal mode of operation, control signal Sn 12782 remains at “1”, meaning that switch N 1278 remains closed, and control signal Ss 12772 remains at “0”, meaning that switch S 1277 remains open. During sleep mode of operation, control signal Sn 12782 remains at “0”, meaning that switch N 1278 remains open, and control signal Ss 12772 remains at “1”, meaning that switch S 1277 remains closed. According to the present disclosure, the number and values of control signals Sn 12782 and Ss 12772 are exemplary and other numbers and values may be

chosen without departing from the scope of the present disclosure. For example, in one embodiment, one control signal Sns similar to control signal 1134 may include two bits, b0 and b1, where b0=Sn and b1=Ss or vice-versa.

[0066] FIG. 12C illustrates a coupling circuit 1280 similar to coupling circuit 1150 in accordance with one embodiment of the present disclosure. Coupling circuit 1280 includes input terminal 1283 (similar to input terminal 658) coupled to resistor 1286. Resistor 1286 is coupled to switch S 1287 (similar to switch S 1277). Coupling circuit 1280 also includes input terminal 1282 (similar to input terminal 1152). Switch S 1287 output and input terminal 1282 are coupled together and to output terminal 1284 (similar to output terminal 1154).

[0067] In operation, when applied to low power device 1100, coupling circuit 1280 selectively couples its output 1154 (or 1284) to regulator 1120 and controller 1130, and receives one control signal 1134 (or 12872) to control the behavior of switch S 1287. According to the present disclosure, when controller 1130 enters normal mode of operation (e.g., as in Figs. 7B-C), control signal 1134 opens switch S 1287. In normal mode of operation, the highest voltage level V1 at terminal 1112 from voltage source 1110 is utilized, or similarly, terminal 862 of voltage source 860. For the example of a battery pack with 2 sets of 2 batteries in series of 1.5V each, regulator 1120 may down-convert the input voltage of 3V down to 2.7V, for example, as required by controller 1130 and other loads (e.g., 1140-1148). In normal mode of operation, the required current draw at the output of coupling circuit 1150 may be, for example, in the order of 0.1A.

[0068] On the other hand, when controller 1130 enters sleep mode of operation (e.g., as in FIG. 7C), control signal 1134 closes switch S 1287. In sleep mode of operation, regulator 1120 is bypassed. For the example of a battery pack with 2 sets of 2 batteries in series of 1.5V each (as in FIG. 8), 3V are provided through a resistor R 1286 to controller 1130 and other loads (e.g., 1140-1148). In sleep mode of operation, the required current draw at the output of coupling circuit 1150 may be, for example, in the order of 1 to 2 μ A and resistor R 1286 may be between 150 and 300 K Ω . Since regulator 1120 may itself draw current in the order of 10 μ A, by bypassing regulator 1120 in sleep mode, the operational life of voltage source 1110, or similarly 860, will improve. More generally, the energy consumption of low power device 1100 will decrease. In a second embodiment of coupling circuit 1280, resistor R 1286 may be removed. In a third embodiment of coupling circuit 1280, resistor R 1286 may be replaced by an LDO regulator.

[0069] Coupling circuit 1280 differs from coupling circuit 1270 in that switch N 1278 of coupling circuit 1270 is always closed in coupling circuit 1280, or equivalently, does not exist in coupling circuit 1280. This fundamental difference permits the output of regulator 1120 of low power device 1100 to always be coupled to controller 1130, whether in normal or sleep mode of operation. In addition, during sleep mode, the control switches of regulator 1120 are kept open. As a result, capacitor C at the output of regulator 1120 does not discharge during sleep mode, maintaining its charge from one normal mode period to the next. Due to residual resistances within practical regulator designs, a loss of charge in capacitor C is possible if regulator 1120 is simply disconnected during sleep mode, for example, by opening switch N 1278 of coupling circuit 1270. As a result, coupling circuit 1280 represents further savings in power consumption, since there is not a need to recharge capacitor C at the output of regulator 1120 when the regulator transitions from sleep to normal mode of operation.

[0070] Control switch S 1287 of coupling circuit 1280 may be controlled by control signal Ss 12872 similarly to control signal 12772, in curve 12775 of FIG. 12B. When in operation, during normal mode, control signal Ss 12872 remains at “0”, meaning that switch S 1287 remains open. During sleep mode of operation, control signal Ss 12872 remains at “1”, meaning that switch S 1287 remains closed. According to the present disclosure, the values of control signal Ss 12872 are exemplary and other values may be chosen without departing from the scope of the present disclosure.

[0071] FIG. 13 illustrates regulator 1300 similar to regulator 700 and 1120 coupled to coupling circuit 1380 similar to coupling circuit 1280 and 1150 in accordance with one embodiment of the present disclosure. Figure 13 shows that capacitor C 1350 is coupled to output terminal 1384. When in operation, during normal mode, switch S 1387 is open (control signal 13872 is at “0”), switch A 1320 is closed (control 1322 is at “1”) and switch B 1330 is open (control 1323 is at “0”). Input voltage V1 at input terminal 1310 drives the output terminal 1384. During sleep mode of operation, switch S 1387 is closed (control signal 13872 is at “1”), and switches A and B are open (controls 1322 and 1323 are at “0”). Input voltage V2 drives the output terminal 1384, maintaining capacitor C 1350 charged throughout sleep mode. This represents further savings in power consumption, since there is not a need to recharge capacitor C 1350 at the output of regulator 1370 when the regulator transitions from sleep to normal mode of operation, as previously explained.

[0072] According to one aspect of the present disclosure, an apparatus 600, 1100 is described for providing an output voltage that decreases power consumption in a low power device. The apparatus includes a voltage source 610, 860, 1110, the voltage source including a first voltage output 612, 862, 1112, 1310 at a first voltage level V1 and a second voltage output 614, 864, 1114, 1383 at a second voltage level V2 lower than the first voltage level, a switch circuit 670, 900, 1170 coupled to the voltage source that alternately selects one of the first voltage level and the second voltage level to output a third voltage level responsive to a first control signal 636, 936, 1136 and a regulator 620, 700, 1120, 1370 coupled to the switch circuit 670, 900, 1170 responsive to a second control signal 632 that outputs a fourth voltage level V3 652, 1152, 1360.

[0073] According to one embodiment of the apparatus, the apparatus may further include a controller 630, 1130 coupled to the regulator 620, 1120 and to the switch circuit 670, 1170 that receives the output voltage and provides the first 636, 1136 and second 632, 1132 control signals to the switch circuit 670, 1170 and to the regulator 620, 1120, respectively.

[0074] According to one embodiment of the apparatus, the voltage source 610, 1120 may be a battery pack.

[0075] According to one embodiment of the apparatus, the battery pack may include at least two sets of batteries, each set including a plurality of batteries coupled in series 860. The at least two sets may be configured in parallel but not connected in parallel.

[0076] According to one embodiment of the apparatus, the second control signal 632, 1132 may be one of a first mode and a second mode. In one embodiment, the first mode may be a normal mode and the second mode may be a sleep mode, the sleep mode being a lower current mode than the normal mode.

[0077] According to one embodiment of the apparatus, the coupling circuit output 654, 874 may be coupled to the regulator 620 when the third control signal 634, 8772, 8782 is set to the first mode and may be coupled to the second voltage output 614 when the third control signal 634, 8772, 8782 is set to the second mode.

[0078] According to one embodiment of the apparatus, the first control signal 636, 1136 may change responsive to the second control signal 632, 1132.

[0079] According to one embodiment of the apparatus, the first control signal 636, 1136 may regularly alternate between a first state and a second state when in operation, the first state

selecting the first voltage level 612, 1112 and the second state selecting the second voltage level 614, 1114.

[0080] According to one embodiment, the apparatus may further include a coupling circuit 650, 1150 that selectively couples a coupling circuit output 654, 1274, 1284, 1384 to at least one of
5 the switch circuit 670, 900, 1170 and the regulator 620, 700, 1120 responsive to a third control signal 634 to provide an output voltage.

[0081] According to one embodiment, the apparatus may further include a controller 630, 1130 coupled to the regulator 620, 700, 1120, to the switch circuit 670, 900, 1170 and to the coupling circuit 650, 1150 that receives the output voltage and provides the first 636, second 632 and third
10 634 control signals to the switch circuit 670, 900, 1170, to the regulator 620, 700, 1170 and to the coupling circuit 650, 1150, respectively.

[0082] According to one embodiment of the apparatus, the coupling circuit output 654, 1154, 1274 may be coupled to the regulator 620, 1120 when the third control signal 634, 1134, 12772, 12782 is set to a first mode and coupled to the switch circuit 670, 900, 1170 when the third
15 control signal 634, 1134, 12772, 12782 is set to a second mode, the second mode being a lower current mode than the first mode.

[0083] According to one embodiment of the apparatus, the regulator 620, 1120 may be a buck regulator 700 further including a first switch 720 and a second switch 730, the first and second switches responsive to the second control signal 632, 722, 732, 1132.

[0084] According to one embodiment of the apparatus, when the third control signal 634, 12772, 12782, 1134 is set to the second mode, the second control signal 632, 722, 732, 1132 may close
20 the first switch 720 and open the second switch 730.

[0085] According to one embodiment of the apparatus, when the third control signal 634, 12772, 12782, 1134 is set to the first mode, the second control signal 632, 722, 732, 1132 may
25 alternately open and close the first switch 720 while, at the same time, alternately closing and opening the second switch 730, respectively, keeping only one switch open or closed at a time. In summary, the first and second switches have opposite behavior, with one closing when the other opens, and vice-versa.

[0086] According to one embodiment of the apparatus, the coupling circuit output 654, 1154, 1284, 1384 may be coupled to the regulator 620, 1120, 1370 when the third control signal 634, 1134, 12872, 13872 is set to the first mode and may be coupled to the switch circuit 670, 900,
30

1170 and to the regulator 620, 1120, 1370 when the third control signal 634, 8872, 9872 is set to the second mode, , the second mode being a lower current mode than the first mode.

[0087] According to one embodiment of the apparatus, the regulator 620, 1120 may be a buck regulator further including a first switch 720, 1320 and a second switch 730, 1330, the first and
5 second switches responsive to the second control signal 632, 1132, 722, 1322, 732, 1332.

[0088] According to one embodiment of the apparatus, when the third control signal 634, 1134, 12872, 12872 is set to the second mode, the second control signal 632, 722, 1322, 732, 1332 may open the first switch 720, 1320 and the second switch 730, 1330.

[0089] According to one embodiment of the apparatus, when the third control signal 634, 1134,
10 12872, 13872 is set to the first mode, the second control signal 632, 1132, 722, 1322, 732, 1332 may alternately open and close the first switch 720, 1320 while, at the same time, alternately closing and opening the second switch 730, 1330, respectively, keeping only one switch open or closed at a time. In summary, the first and second switches have opposite behavior, with one closing when the other opens, and vice-versa.

[0090] According to one embodiment of the apparatus, the apparatus may further include at
15 least one functional component 640-648, 1140-1148 coupled to the controller 630, 1130.

[0091] According to one embodiment of the apparatus, the coupling circuit 650, 1150 may include FET transistors.

[0092] FIG. 14 illustrates a flowchart of an exemplary method of providing an output voltage
20 that decreases power consumption in a low power device in accordance with one aspect of the present disclosure. The method includes, at step 1410, accessing or providing a first voltage at a first voltage level and a second voltage at a second voltage level. The step 1410 may be performed by, for example, voltage source 610, 1110 or 860.

[0093] Next, at step 1420, the method includes alternately selecting one of the first voltage and
25 the second voltage to output a third voltage responsive to a first control signal. The step of alternately selecting 1420 may be performed by, for example, switch circuit 670, 900 or 1170.

[0094] Finally, at step 1430, the method includes regulating in a regulator the first voltage responsive to a second control signal to output a fourth voltage. The step of regulating 1430 may be performed by, for example, regulator 620, 720 or 1120.

[0095] In one embodiment, the method may further include receiving, at step 1450, the output
30 voltage and generating, at step 1460, the control signals. The control signals may include, in one

embodiment, the first control signal and the second control signal. In another embodiment, the control signals may include the first control signal, the second control signal and a third control signal. The steps of receiving the voltage output and generating may be performed by, for example, controller 630 or 1130. In at least one embodiment of the method, the steps of receiving and generating may be bypassed or removed.

[0096] In one embodiment of the method, the first and second voltages may be provided by a battery pack. The battery pack may be, for example, battery pack 860. In another embodiment of the method, the voltage source may be, for example, a rectified AC source, as previously explained.

[0097] In one embodiment of the method, the battery pack may include at least two sets of batteries, each set including a plurality of batteries coupled in series. The at least two battery sets may be configured in parallel but not connected in parallel. The battery pack may be, for example, battery pack 860.

[0098] In one embodiment of the method, the second control signal may be one of a first mode and a second mode. In one embodiment, the first mode of the second control signal may be a normal mode and the second mode of the second control signal may be a sleep mode the sleep mode being a lower current mode than the normal mode. The normal mode and sleep mode may be as previously described in relation to regulators 700 or 970. The second control signal may be, for example, control signal 632 or 1132.

[0099] In one embodiment of the method, the first control signal may change responsive to the second control signal.

[0100] In one embodiment of the method, the first control signal may regularly alternate between a first state and a second state when in operation, the first state selecting the first voltage and the second state selecting the second voltage.

[0101] In one embodiment, the method may further include, at step 1440, selectively coupling an output to at least one of the third voltage and the regulator responsive to the previously mentioned third control signal in order to provide an output voltage. The step of selectively coupling 1440 may be performed by, for example, coupling circuit 1150, 1270, 1280 or 1380. In at least one embodiment of the method, the step of selectively coupling is optional and may be bypassed or removed.

[00102] In one embodiment of the method, the third control signal may be one of a first mode and a second mode. In one embodiment, the first mode of the third control signal may be a normal mode and the second mode of the third control signal may be a sleep mode, the sleep mode being a lower current mode than the normal mode. The normal mode and sleep mode may be as
5 previously described in relation to regulators 700 or 970. The third control signal may be, for example, control signal 634 or 1134.

[00103] In one embodiment of the method, the step of selectively coupling may further include coupling the output to the regulator when the third control signal is set to the first mode, and coupling the output to the third voltage when the third control signal is set to the second mode.

10 The step of coupling may be performed, for example, by coupling circuit 1150 or 1270.

[00104] In one embodiment of the method, the step of regulating may be performed by a buck regulator, the step of regulating further including switching a first switch and a second switch within the regulator responsive to the second control signal. The step of regulating may be performed, for example, by regulator 620, 700 or 1120.

15 [00105] In one embodiment of the method, the step of switching may further include, when the third control signal is set to the second mode, setting the second control signal to close the first switch and open the second switch. The step of regulating may be performed, for example, by regulator 620, 700 or 1120 and the step of switching may be as explained in Figs. 7A-7C.

[00106] In one embodiment of the method, the step of switching may further include, when the
20 third control signal is set to the first mode, setting the second control signal to, at the same time, alternately open and close the first switch and the second switch, keeping only one switch open or closed at a time. The step of regulating may be performed, for example, by regulator 620, 700 or 1120 and the step of switching may be as explained in Figs. 7A-7C.

[00107] In one embodiment of the method, the step of selectively coupling may further include
25 coupling the output to the regulator when the third control signal is set to the first mode, and coupling the output to the second voltage output and to the regulator when the third control signal is set to the second mode. The step of coupling may be performed, for example, by coupling circuit 1150, 1280 or 1380.

[00108] In one embodiment of the method, the step of regulating may be performed by a buck
30 regulator, the regulating step further including switching a first switch and a second switch

within the regulator responsive to the second control signal. The step of regulating may be performed, for example, by regulator 1120, 1370.

[00109] In one embodiment of the method, the step of switching may further include, when the third control signal is set to the second mode, setting the second control signal to open the first switch and the second switch. The step of regulating may be performed, for example, by regulator 700, 1120 or 1370 and the step of switching may be as explained in the description of Figs. 12C and 13.

[00110] In one embodiment of the method, the step of switching may further include, when the third control signal is set to the first mode, setting the second control signal to at the same time, alternately open and close the first switch and the second switch, keeping only one switch open or closed at a time. The step of regulating may be performed, for example, by regulator 700, 1120, 1370 and the step of switching may be as explained in Figs. 7B-7C.

[00111] In one embodiment, the method may further include coupling, at step 1470, to at least one functional component. In at least one embodiment of the method, the step of coupling to at least one functional component may be bypassed or removed. The step of coupling may be performed by, for example, controller 630. The functional components may be components 640-648 or 1140-1148.

[00112] In one embodiment of the method, the step of selectively coupling may further include using FET transistors as switches.

[00113] It is to be understood that the embodiments of the method 1400 described above may be implemented by apparatus 600 or 1100 and their respective embodiments described in FIGs. 7A to 10, 12 and 13. It is to be further understood that additional embodiments of the voltage source 610, 1110, switch circuit 670, 1170, regulator 620, 1120, coupling circuit 650, 1150, controller 630, 1130 and functional components 640-648, 1140-1148, as previously described in the present disclosure, may also implement their respective steps of the method of flowchart 1400.

[00114] According to one aspect of the present disclosure, an apparatus 600, 1100 is described for providing an output voltage including a voltage source means 610, 1110 including a first voltage output at a first voltage level 612, 1112 and a second voltage output at a second voltage level 614, 1114, means for alternately selecting 670, 900, 1170 one of the first voltage output and the second voltage output to output a third voltage level responsive to a first control signal and

means for regulating 620, 1120 the third voltage level responsive to a second control signal to output a fourth voltage level.

[00115] As noted before, the functions of the various elements shown in the figures may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. Also, when provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared.

[00116] It is to be further understood that, because some of the constituent system components and methods depicted in the accompanying drawings are preferably implemented in software, the actual connections between the system components or the process function blocks may differ depending upon the manner in which the present disclosure is programmed. Given the teachings herein, one of ordinary skill in the pertinent art will be able to contemplate these and similar implementations or configurations of the present disclosure.

[00117] Although the illustrative embodiments have been described herein with reference to the accompanying drawings, it is to be understood that the present disclosure is not limited to those precise embodiments, and that various changes and modifications may be effected therein by one of ordinary skill in the pertinent art without departing from the scope of the present disclosure. In addition, individual embodiments can be combined, without departing from the scope of the present disclosure. All such changes and modifications are intended to be included within the scope of the present disclosure as set forth in the appended claims.

CLAIMS

1. An apparatus (600) comprising:

5 a voltage source (610, 860, 1110) including a first voltage output (612, 862, 1112, 1310) at a first voltage level (V1) and a second voltage output (614, 1114, 864, 1383) at a second voltage level (V2);

a switch circuit (670, 900, 1170) coupled to voltage source that alternately selects one of said first voltage level and said second voltage level to output a third voltage level responsive to a first control signal (636, 936, 1136); and

10 a regulator (620, 700, 1120, 1370) coupled to said switch circuit (670, 900, 1170) responsive to a second control signal (632) that outputs a fourth voltage level (V3) (652, 1152, 1360).

2. The apparatus of claim 1 further comprising:

15 a controller (630, 1130) coupled to said regulator (620, 1120) that receives said output voltage and provides said first (636, 1136) and second (632, 1132) control signals to said switch circuit (670, 1170) and to said regulator (620, 1120), respectively.

3. The apparatus of claim 1 wherein said voltage source (610, 1120) is a battery pack.

- 20 4. The apparatus of claim 3 wherein said battery pack includes at least two sets of batteries, each set including a plurality of batteries coupled in series (860).

5. The apparatus of claim 1 wherein said second control signal (632, 1132) is one of a first mode and a second mode, said second mode being a lower current mode than said first mode.

- 25 6. The apparatus of claim 5 wherein said first control signal (636, 1136) changes responsive to said second control signal (632, 1132).

7. The apparatus of claim 1 wherein said first control signal (636, 1136) regularly alternates between a first state and a second state when in operation, said first state selecting said first voltage level (612, 1112) and said second state selecting said second voltage level (614, 1114).
- 5
8. The apparatus of claim 1 further comprising:
- a coupling circuit (650, 1150) that selectively couples a coupling circuit output (654, 1274, 1284, 1384) to at least one of said switch circuit (670, 900, 1170) and said regulator (620, 700, 1120) responsive to a third control signal (634) to provide an output
- 10 voltage.
9. The apparatus of claim 8 further comprising:
- a controller (630, 1130) coupled to said coupling circuit (650, 1150) that receives said output voltage and provides said first (636), second (632) and third (634) control
- 15 signals to said switch circuit (670, 900, 1170), to said regulator (620, 700, 1170) and to said coupling circuit (650, 1150), respectively.
10. The apparatus of claim 8 wherein said coupling circuit output (654, 1154, 1274) is
- 20 coupled to said regulator (620, 1120) when said third control signal (634, 1134, 12772, 12782) is set to a first mode and coupled to said switch circuit (670, 900, 1170) when said third control signal (634, 1134, 12772, 12782) is set to a second mode, said second mode being a lower current mode than said first mode.
- 25 11. The apparatus of claim 10 wherein said regulator (620, 1120) is a buck regulator (700) further comprising:
- a first switch (720) and a second switch (730), said first and second switches responsive to said second control signal (632, 722, 732, 1132) wherein, when said third control signal (634, 12772, 12782, 1134) is set to said second mode, said second control
- 30 signal (632, 722, 732, 1132) closes said first switch (720) and opens said second switch (730).

12. The apparatus of claim 11 wherein, when said third control signal (634, 12772, 12782, 1134) is set to said first mode, said second control signal (632, 722, 732, 1132) alternately opens and closes said first switch (720) while alternately closing and opening said second switch (730), respectively, keeping only one switch open or closed at a time.

5

13. The apparatus of claim 8 wherein said coupling circuit output (654, 1154, 1284, 1384) is coupled to said regulator (620, 1120, 1370) when said third control signal (634, 1134, 12872, 13872) is set to a first mode and coupled to said switch circuit (670, 900, 1170) and to said regulator (620, 1120, 1370) when said third control signal (634, 1134, 12872, 13872) is set to a second mode, said second mode being a lower current mode than said first mode.

10

14. The apparatus of claim 13 wherein said regulator (620, 1120) is a buck regulator (700, 1370) further comprising:

15 a first switch (720, 1320) and a second switch (730, 1330), said first and second switches responsive to said second control signal (632, 1132, 722, 1322, 732, 1332) wherein, when said third control signal (634, 1134, 12872, 13872) is set to said second mode, said second control signal (632, 1132, 722, 1322, 732, 1332) opens said first switch (720, 1320) and said second switch (730, 1330).

20

15. The apparatus of claim 2 or 9 further comprising at least one functional component (640-648, 1140-1148) coupled to said controller (630, 1130).

16. A method comprising:

25 providing (1410) a first voltage and a second voltage ;
 alternately selecting (1420) one of said first voltage and said second voltage to output a third voltage responsive to a first control signal; and
 regulating (1430) in a regulator said third voltage responsive to a second control signal to output a fourth voltage.

30

17. The method of claim 16 further comprising:

receiving said output voltage (1450); and
generating (1460) said first control signal and said second control signal in a
controller.

5 18. The method of claim 16 wherein said first and second voltages are provided by a battery
pack.

19. The method of claim 18 wherein said battery pack includes at least two sets of batteries,
each set including a plurality of batteries coupled in series.

10 20. The method of claim 16 wherein said second control signal is one of a first mode and a
second mode, said second mode being a lower current mode than said first mode.

15 21. The method of claim 20 wherein said first control signal changes responsive to said
second control signal.

22. The method of claim 16 wherein said first control signal regularly alternates between a
first state and a second state when in operation, said first state selecting said first voltage
and said second state selecting said second voltage.

20 23. The method of claim 16 further comprising:
selectively coupling (1440) an output to at least one of said third voltage and said
regulator responsive to a third control signal to provide an output voltage.

25 24. The method of claim 23 further comprising:
receiving said output voltage (1450); and
generating (1460) said first control signal, said second control signal and said
third control signal.

30 25. The method of claim 23 wherein said selectively coupling further comprises:
coupling said output to said regulator when said third control signal is set to a first
mode; and

coupling said output to said third voltage when said third control signal is set to said second mode, said second mode being a lower current mode than said first mode.

26. The method of claim 25 wherein said regulating is performed by a buck regulator, said regulating further comprising:

switching a first switch and a second switch within said regulator responsive to said second control signal wherein, when said third control signal is set to said second mode, setting said second control signal to close said first switch and open said second switch .

27. The method of claim 26 wherein said switching further comprises:

when said third control signal is set to said first mode, setting said second control signal to alternately open and close said first switch while alternately opening and closing said second switch, keeping only one switch open or closed at a time.

28. The method of claim 23 wherein said selectively coupling further comprises:

coupling said output to said regulator when said third control signal is set to said first mode; and

coupling said output to said third voltage and to said regulator when said third control signal is set to said second mode, said second mode being a lower current mode than said first mode.

29. The method of claim 28 wherein said regulating is performed by a buck regulator, said regulating further comprising:

switching a first switch and a second switch within said regulator responsive to said second control signal wherein, when said third control signal is set to said second mode, setting said second control signal to open said first switch and said second switch.

30. The method of claim 17 or 24 further comprising:

coupling (1470) to at least one functional component.

31. An apparatus comprising:

a voltage source means (610, 1110) including a first voltage output at a first voltage level (612, 1112) and a second voltage output at a second voltage level (614, 1114);

5 means for alternately selecting (670, 900, 1170) one of said first voltage output and said second voltage output to output a third voltage level responsive to a first control signal; and

means for regulating (620, 1120) said third voltage level responsive to a second control signal to output a third voltage level.

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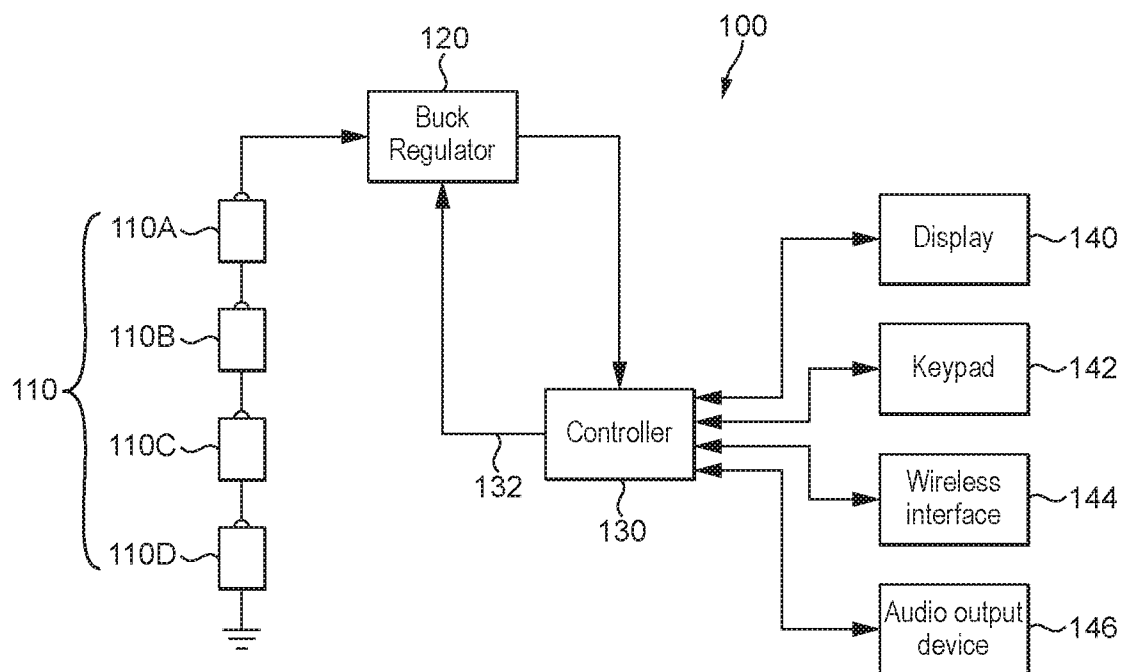


FIG. 1
PRIOR ART

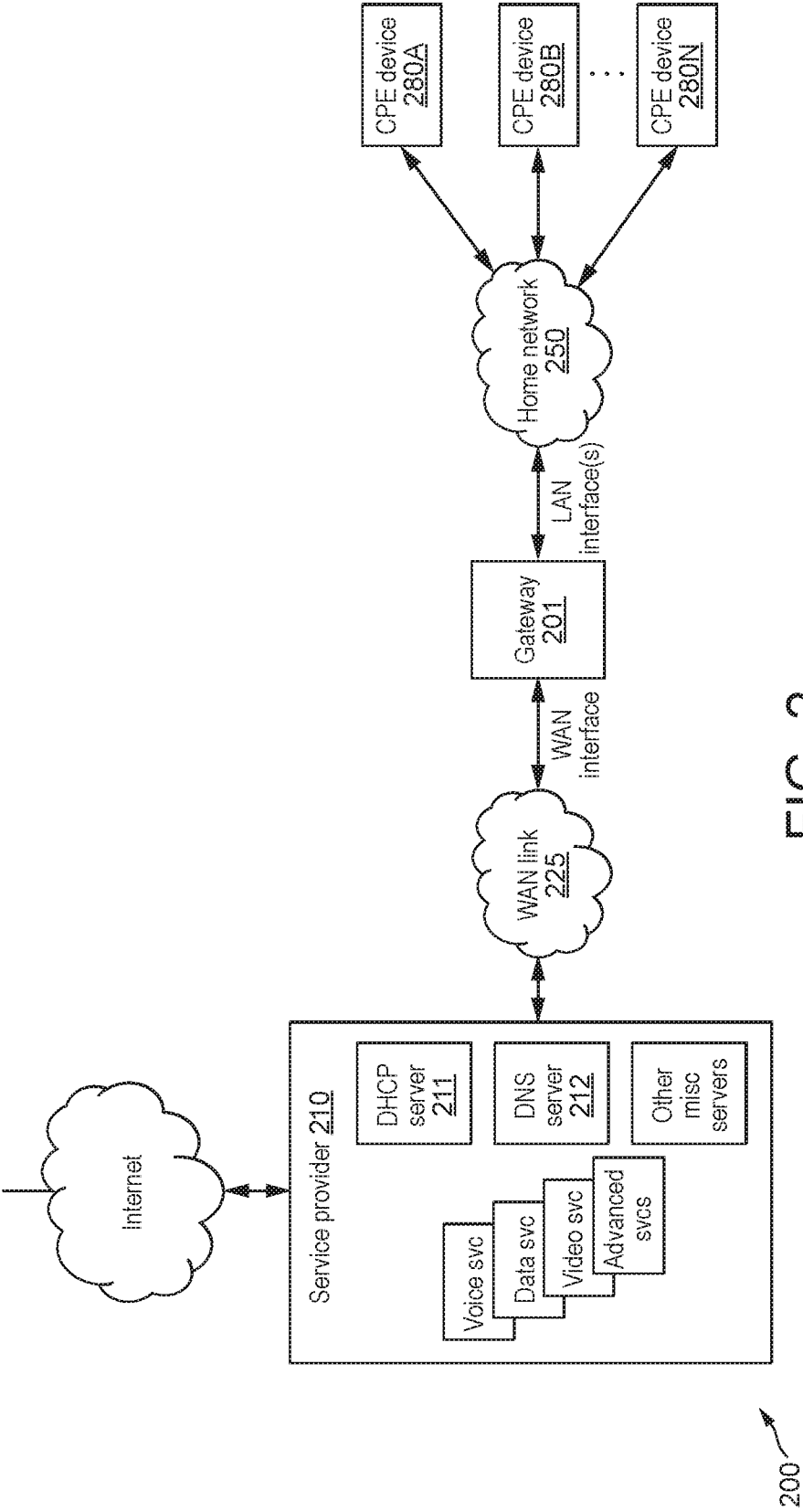


FIG. 2

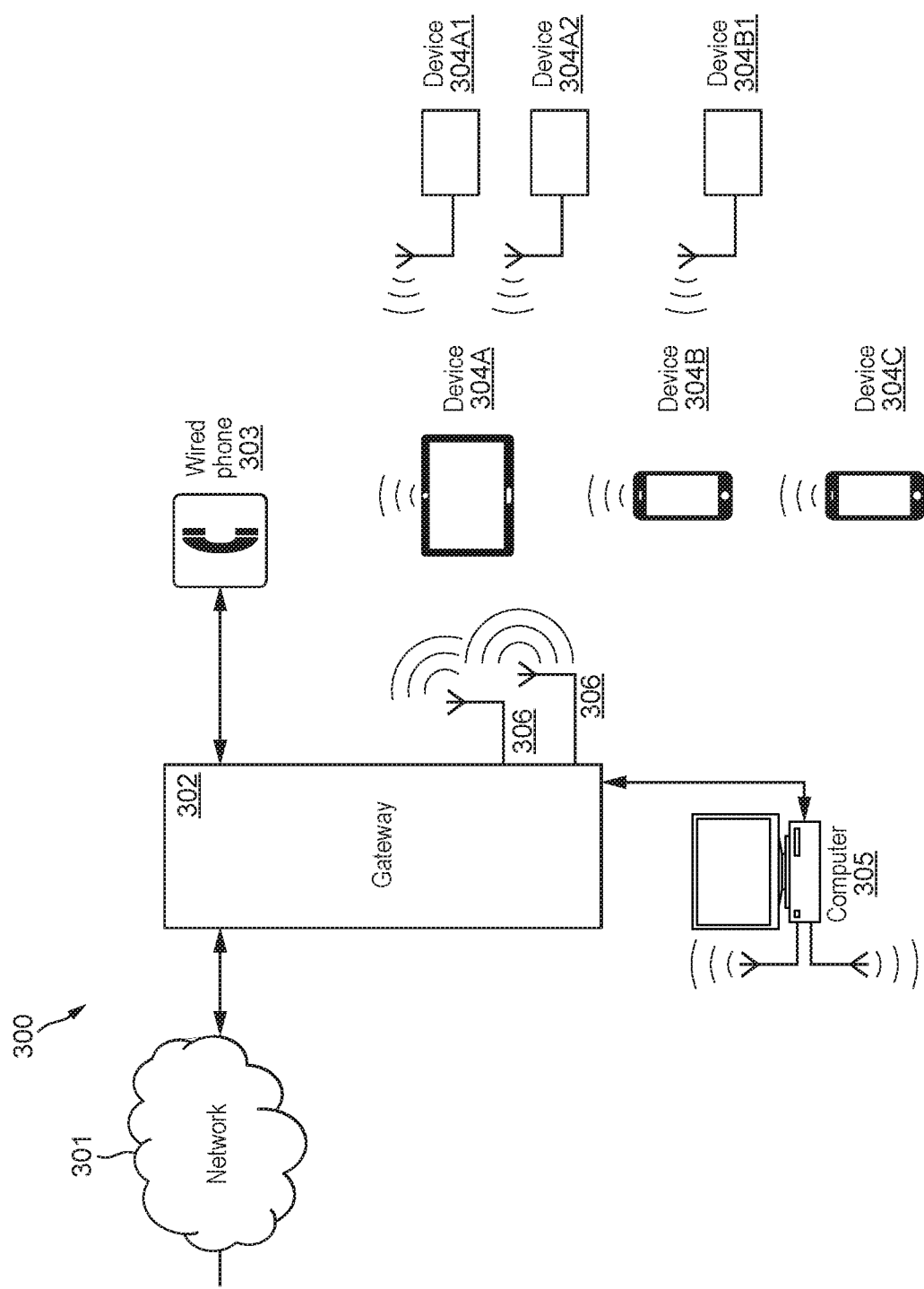


FIG. 3

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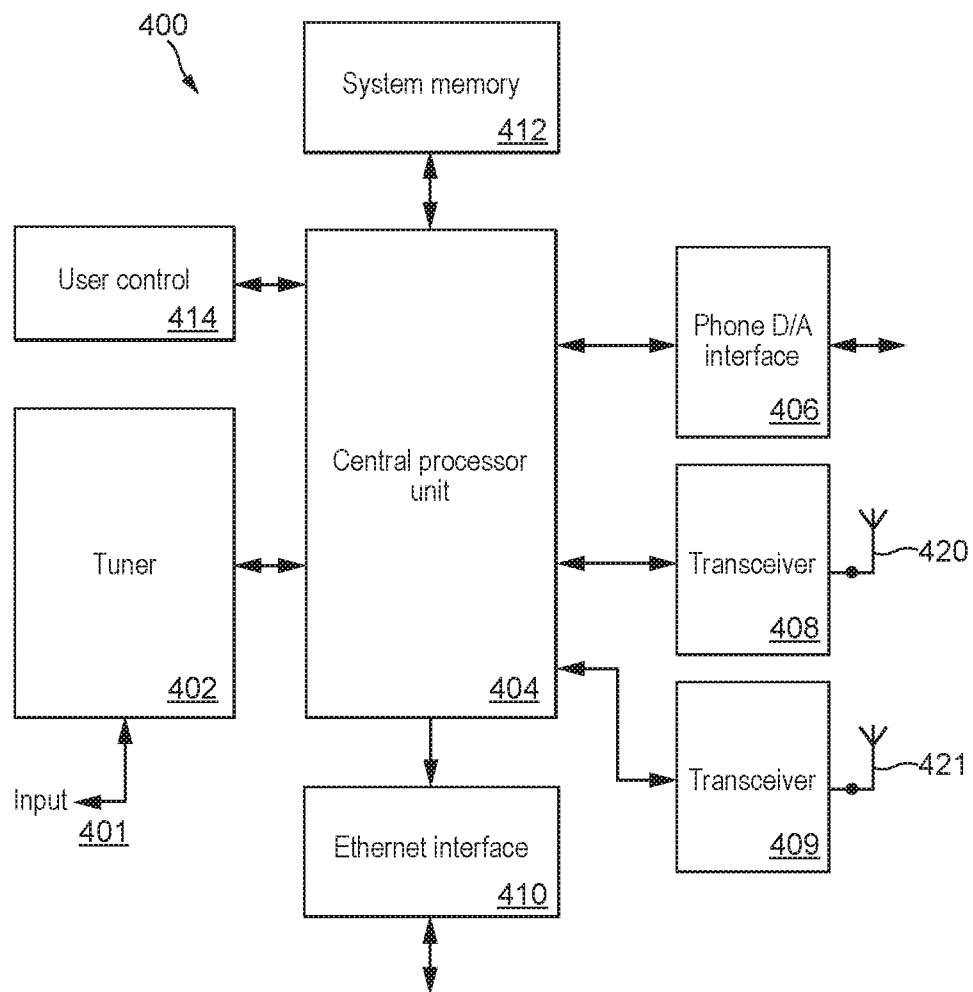
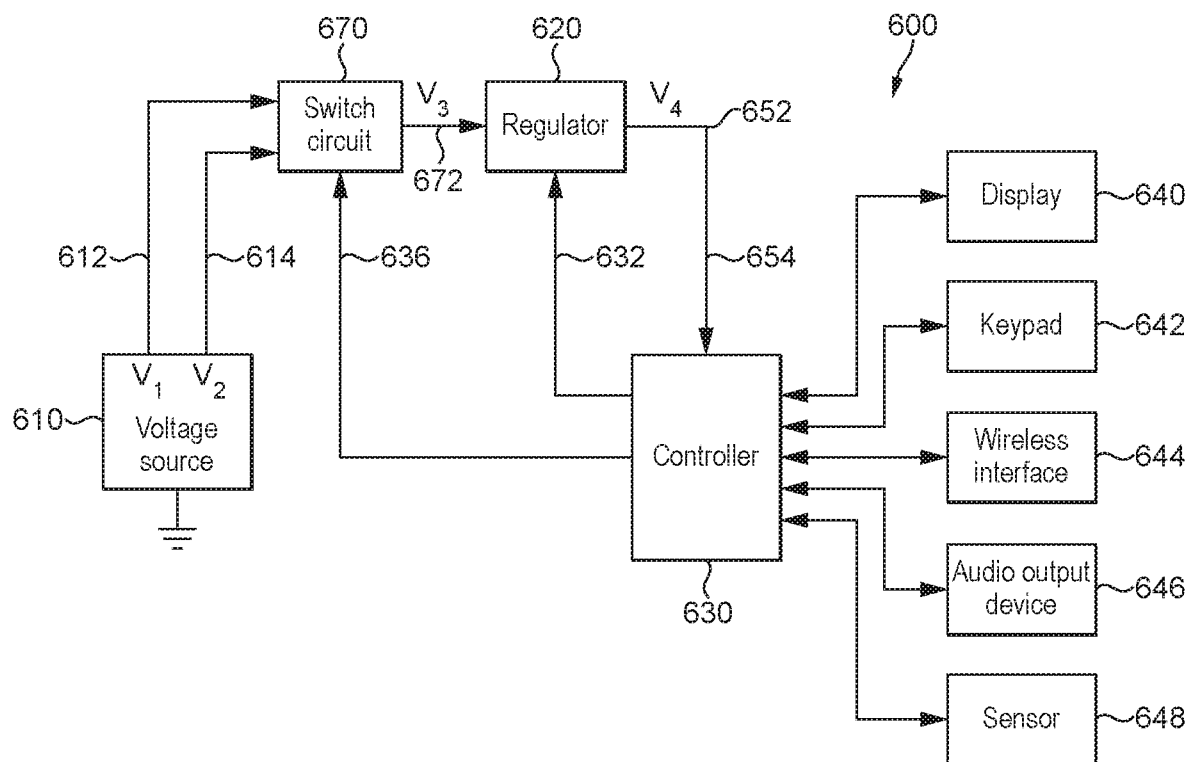
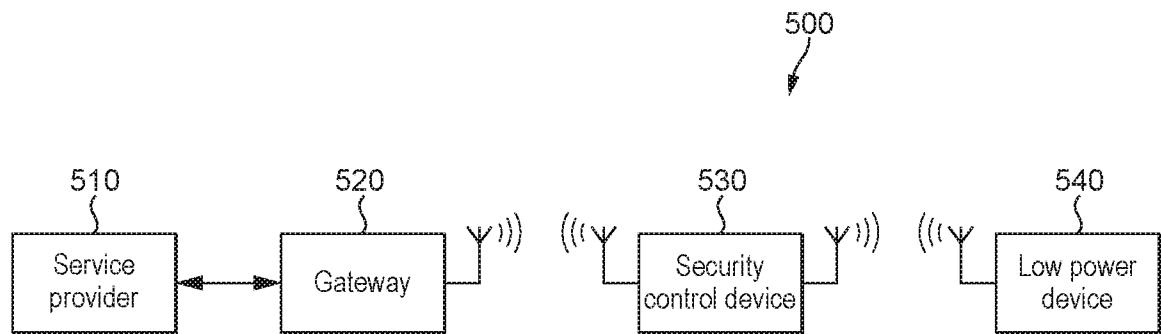


FIG. 4

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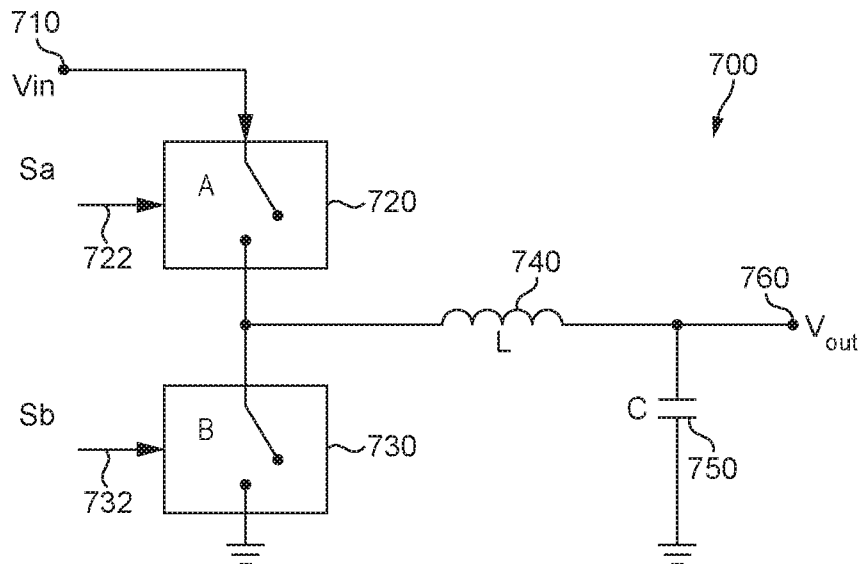


FIG. 7A

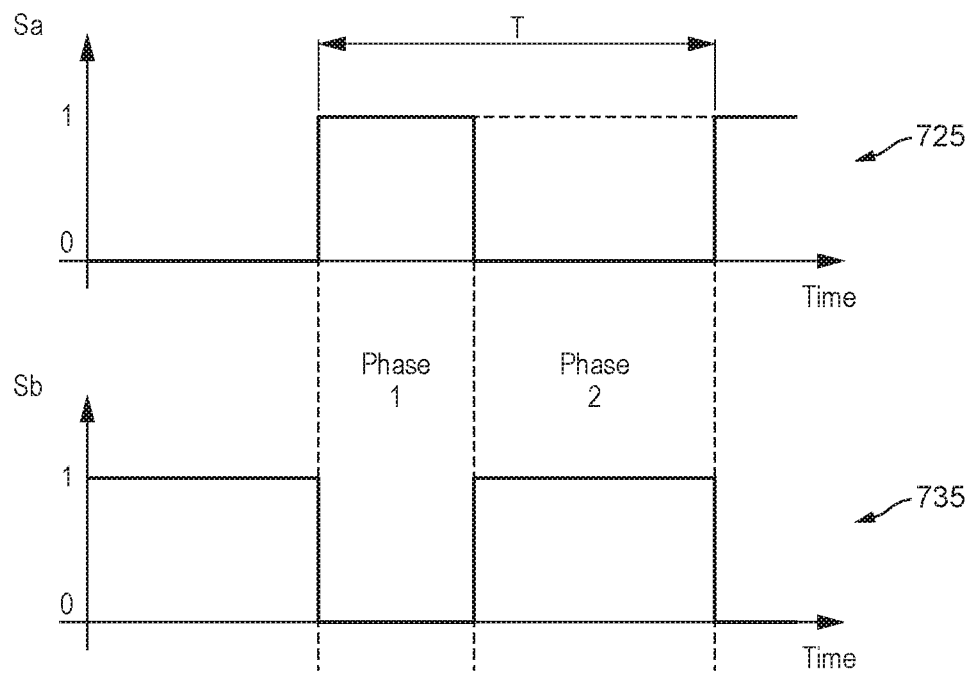


FIG. 7B

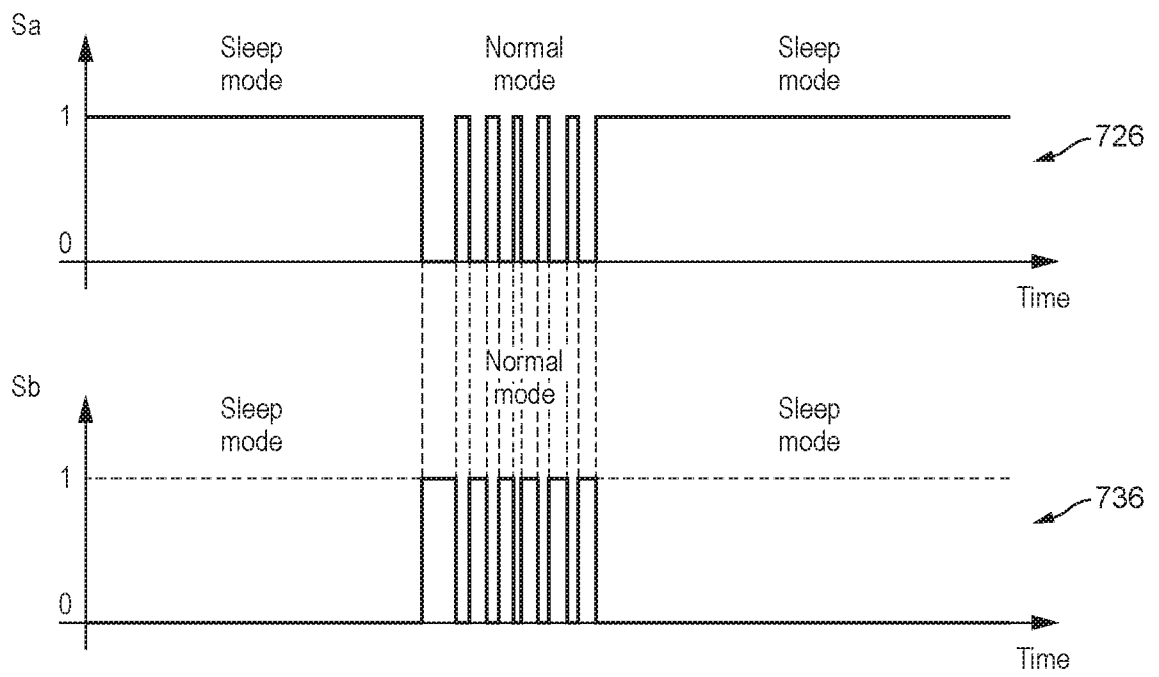


FIG. 7C

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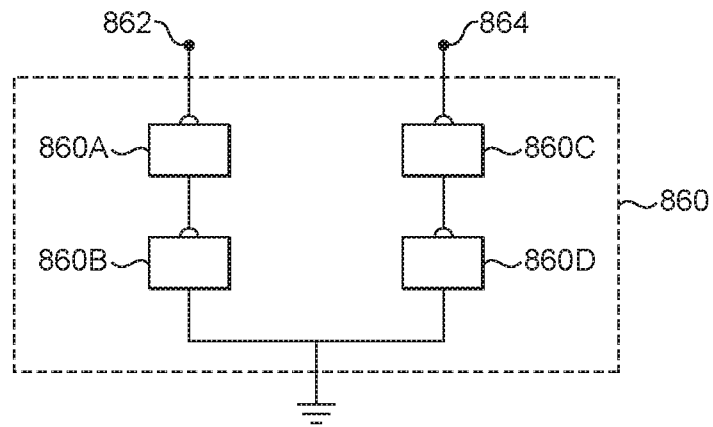


FIG. 8

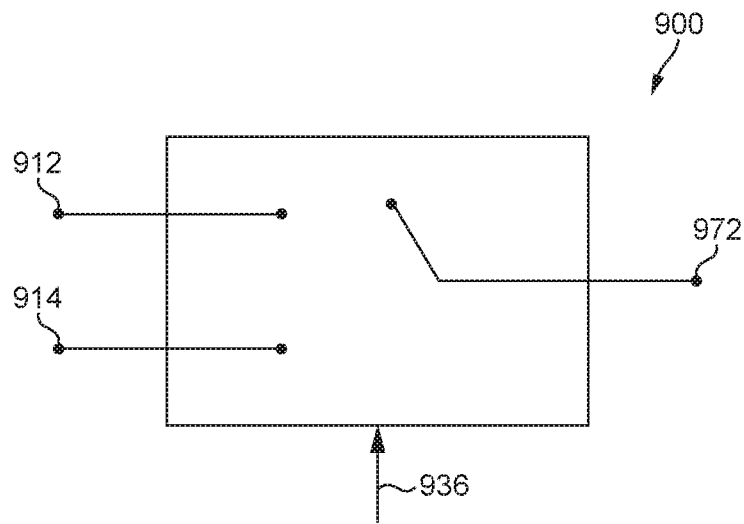


FIG. 9

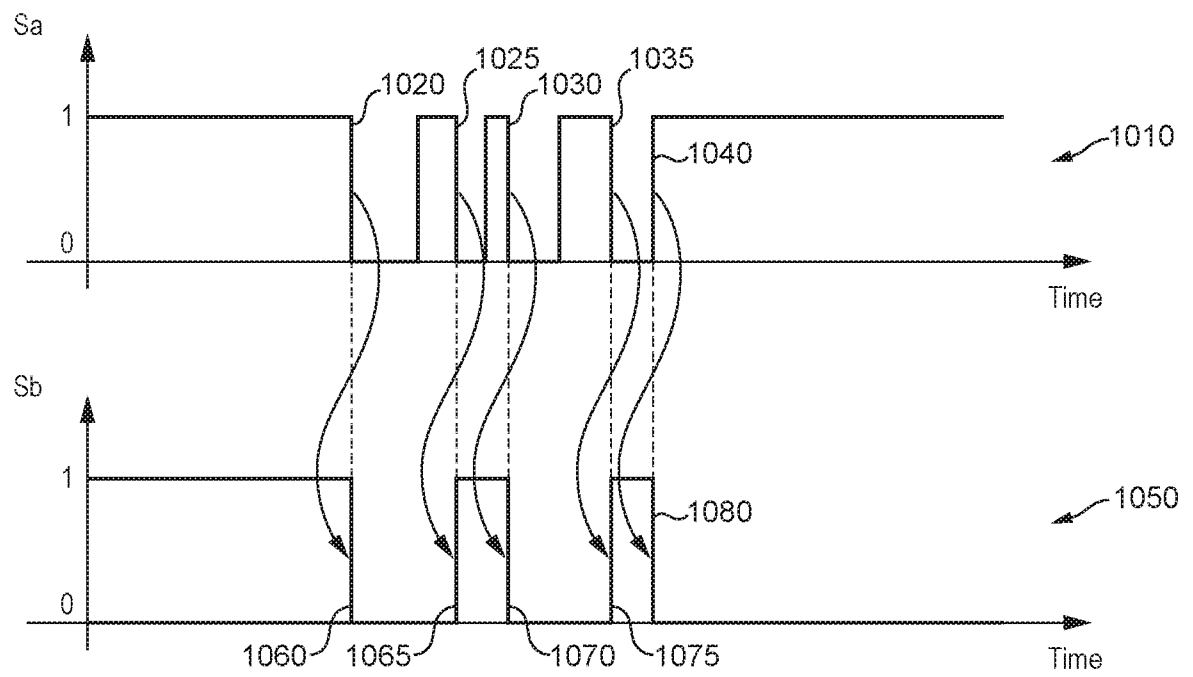


FIG. 10

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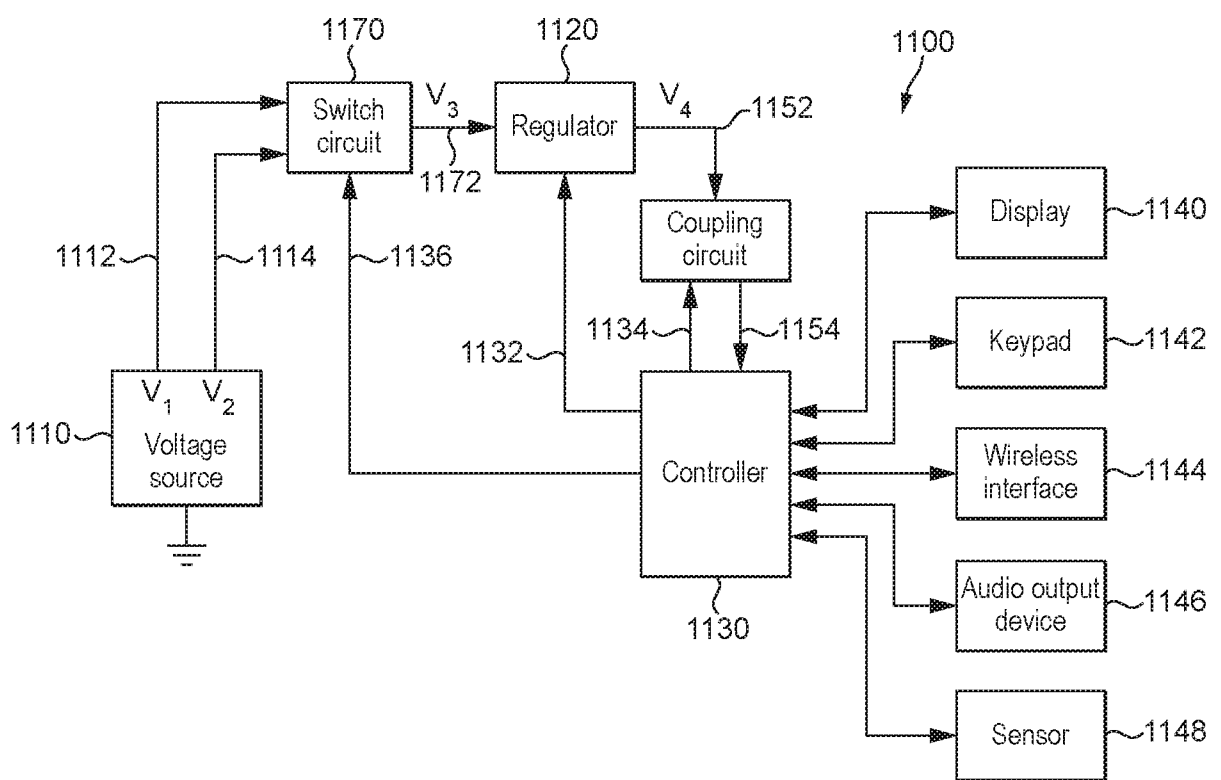


FIG. 11

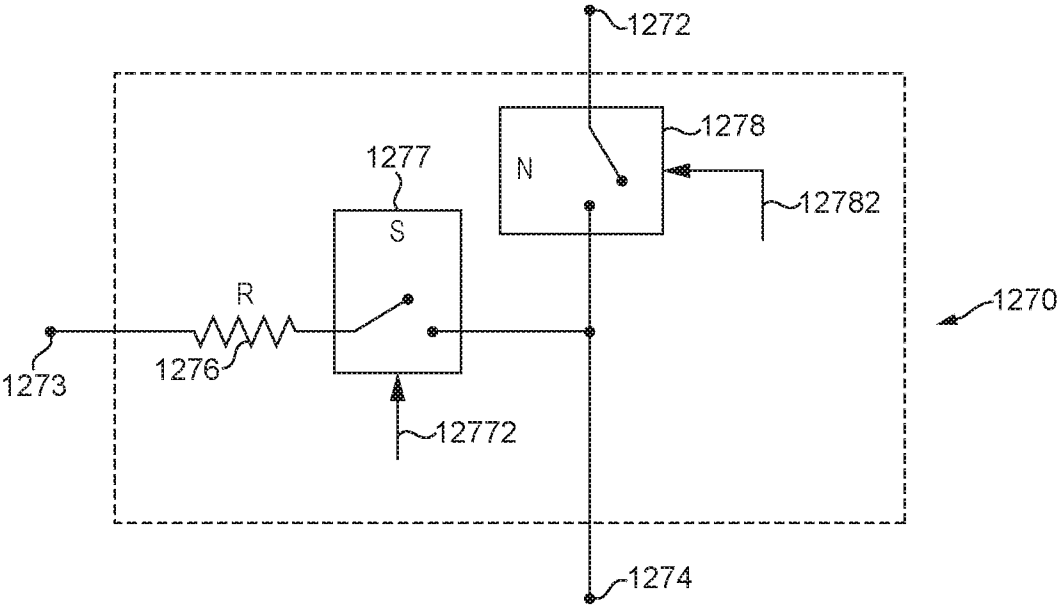


FIG. 12A

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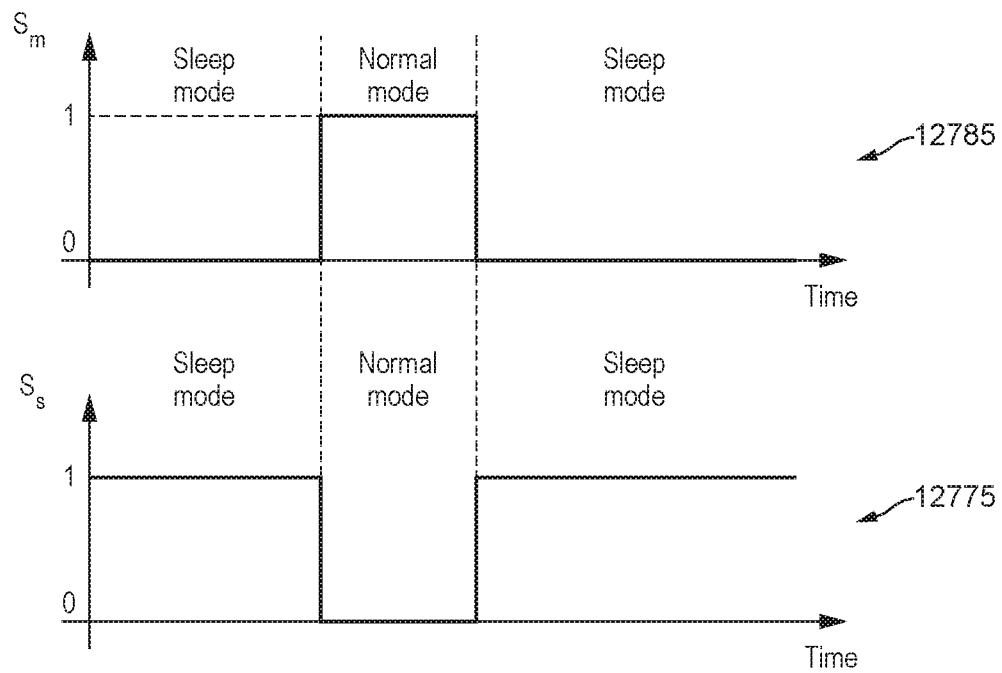


FIG. 12B

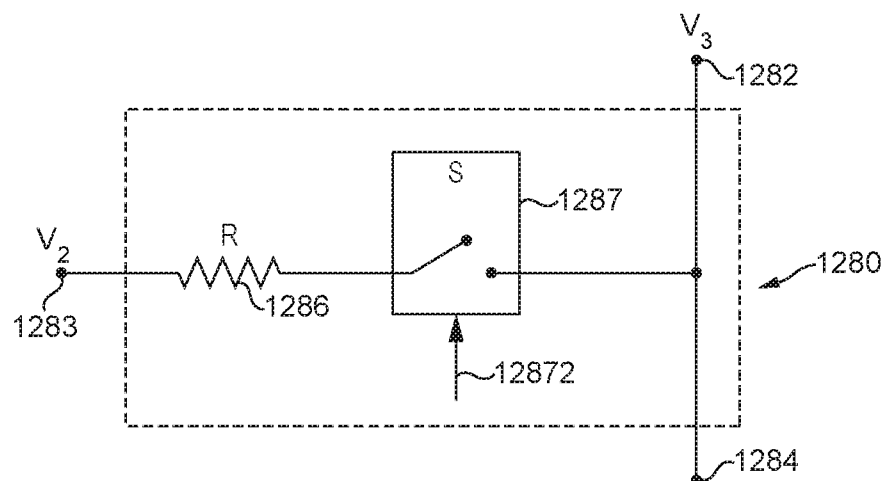


FIG. 12C

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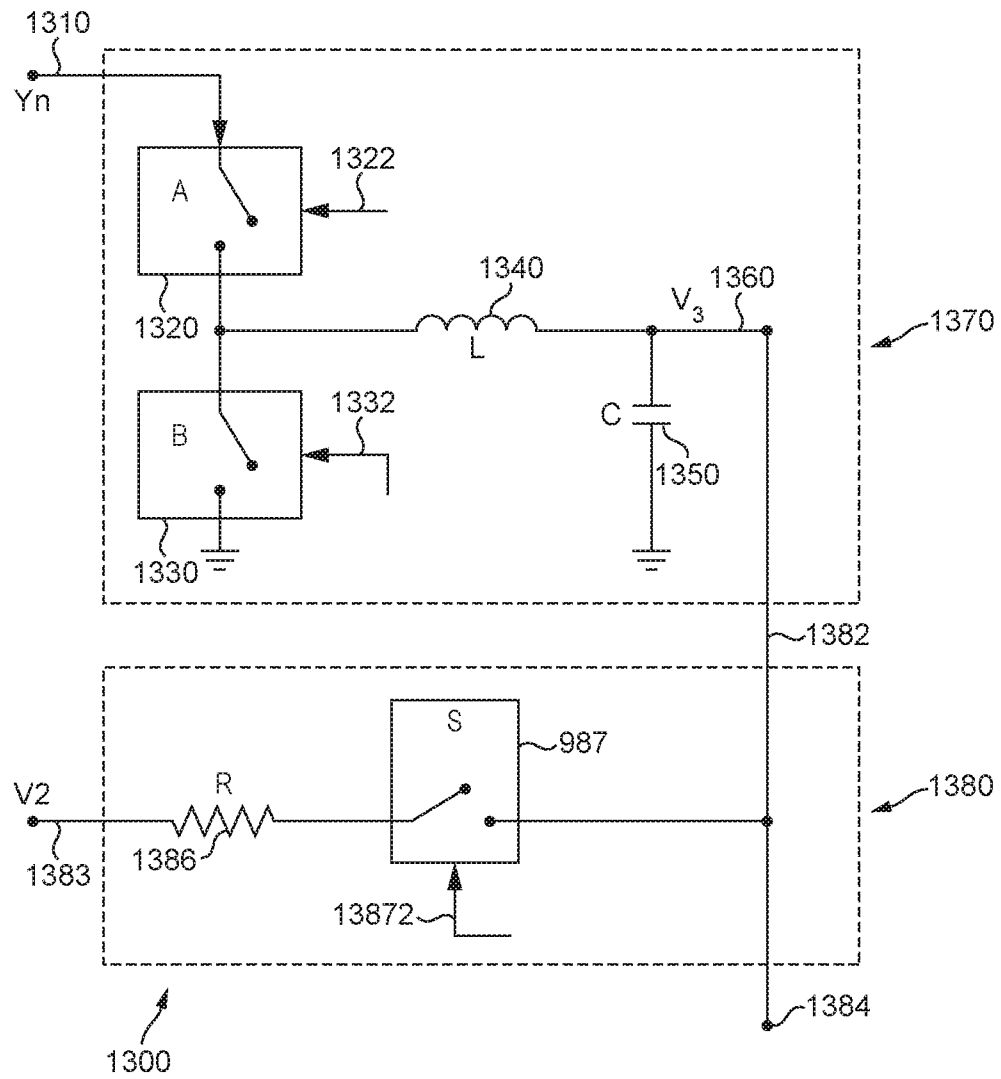


FIG. 13

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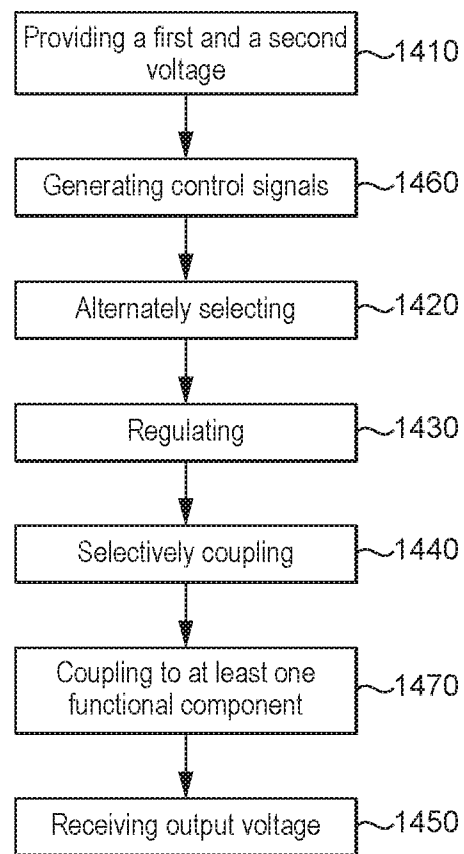


FIG. 14

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/037846

A. CLASSIFICATION OF SUBJECT MATTER
INV. H02J9/00
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)
H02J G06F H02M

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.
X	US 2013/241296 A1 (KUNG NIEN-HUI [TW]) 19 September 2013 (2013-09-19) the whole document	1-31
X	US 2010/213897 A1 (TSE LAWRENCE TZE-LEUNG [US]) 26 August 2010 (2010-08-26) the whole document	1-31
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	----- -/-	



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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Date of the actual completion of the international search

18 November 2016

Date of mailing of the international search report

28/11/2016

Name and mailing address of the ISA/

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Authorized officer

Tille, Daniel

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/037846

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

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International application No

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