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Sherman et al.

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(54) **BI-DIRECTIONAL POWER CONTROL**

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(51) **Int. Cl.**
G06F 19/00 (2011.01)

(52) **U.S. Cl.** **700/286**; 713/310

(58) **Field of Classification Search** 700/286; 710/15–19, 64, 72–74, 300, 104; 713/310
See application file for complete search history.

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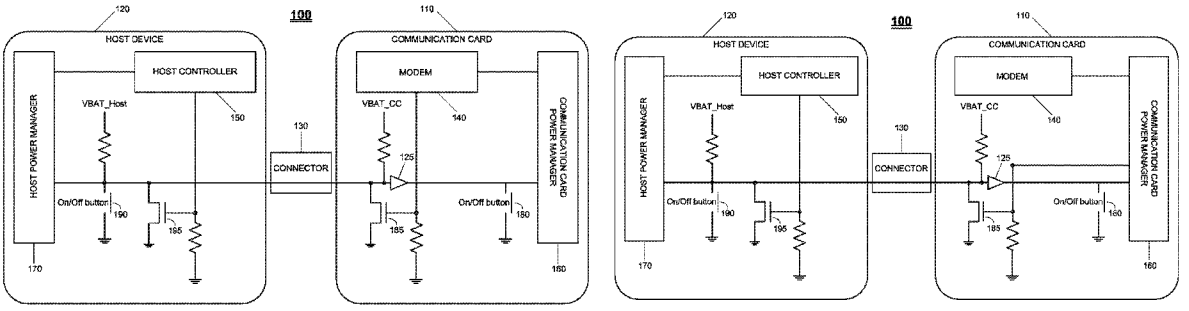
(57) **ABSTRACT**

An electrical circuit for bi-directional power control between two devices, including a first battery-operated device, including a first battery for providing a source of power to the first battery-operated device, a first power management subsystem connected to the first battery, to power on and power off components of the first battery-operated device in response to a first wakeup event, WE_1, and a first on/off button for generating WE_1, a second battery-operated device, including a second battery for providing a source of power to the second battery-operated device, a second power management subsystem connected to the second battery, to power on and power off components of the second battery-operated device in response to a second wakeup event WE_2, a second on/off button for generating WE_2, and a switch for generating WE_1 simultaneously when the second on/off button generates WE_2, and circuitry including a single connection inter-connecting the first power management subsystem, the first on/off button, the second power management subsystem, the second on/off button, and the switch for generating WE_1.

12 Claims, 4 Drawing Sheets



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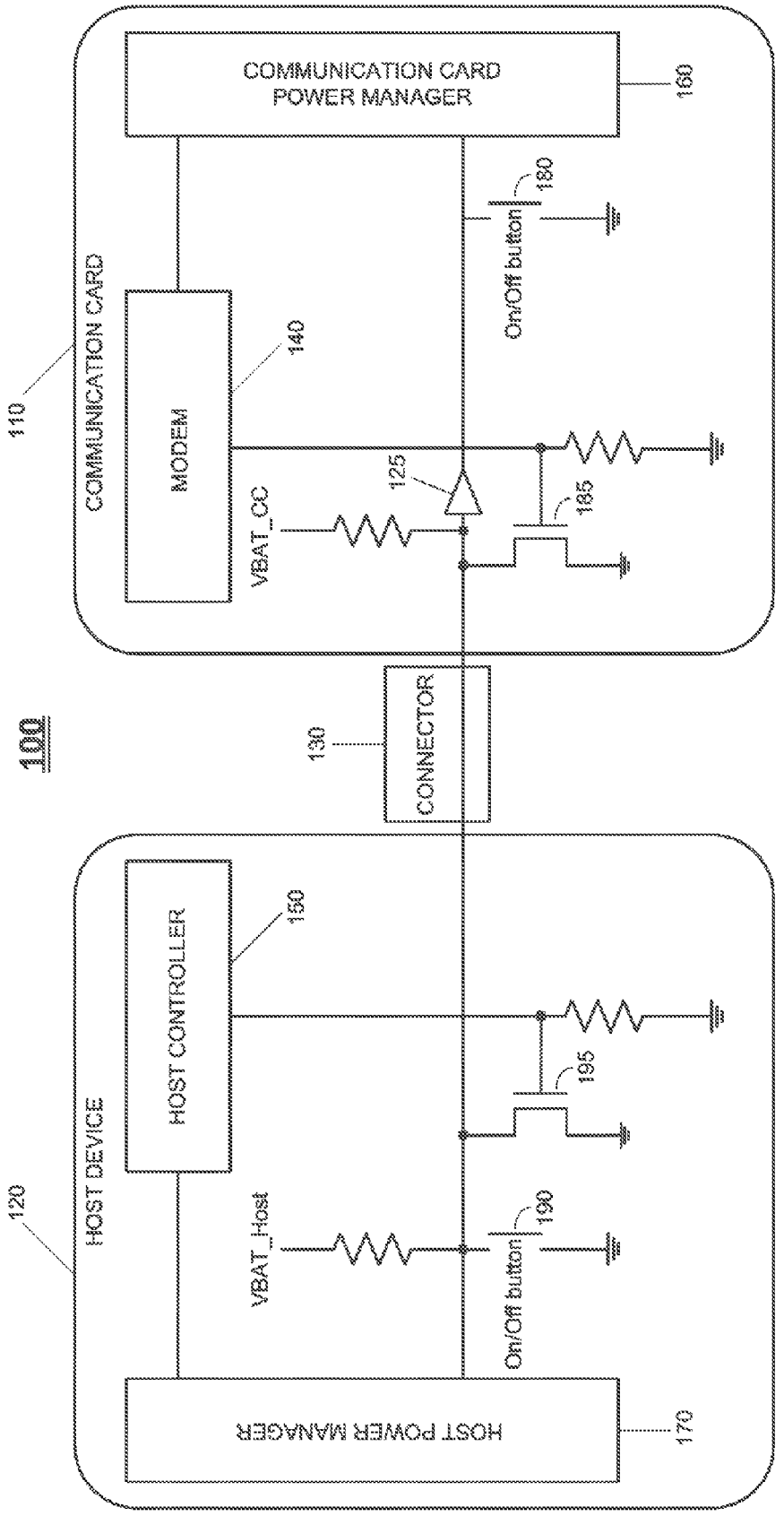
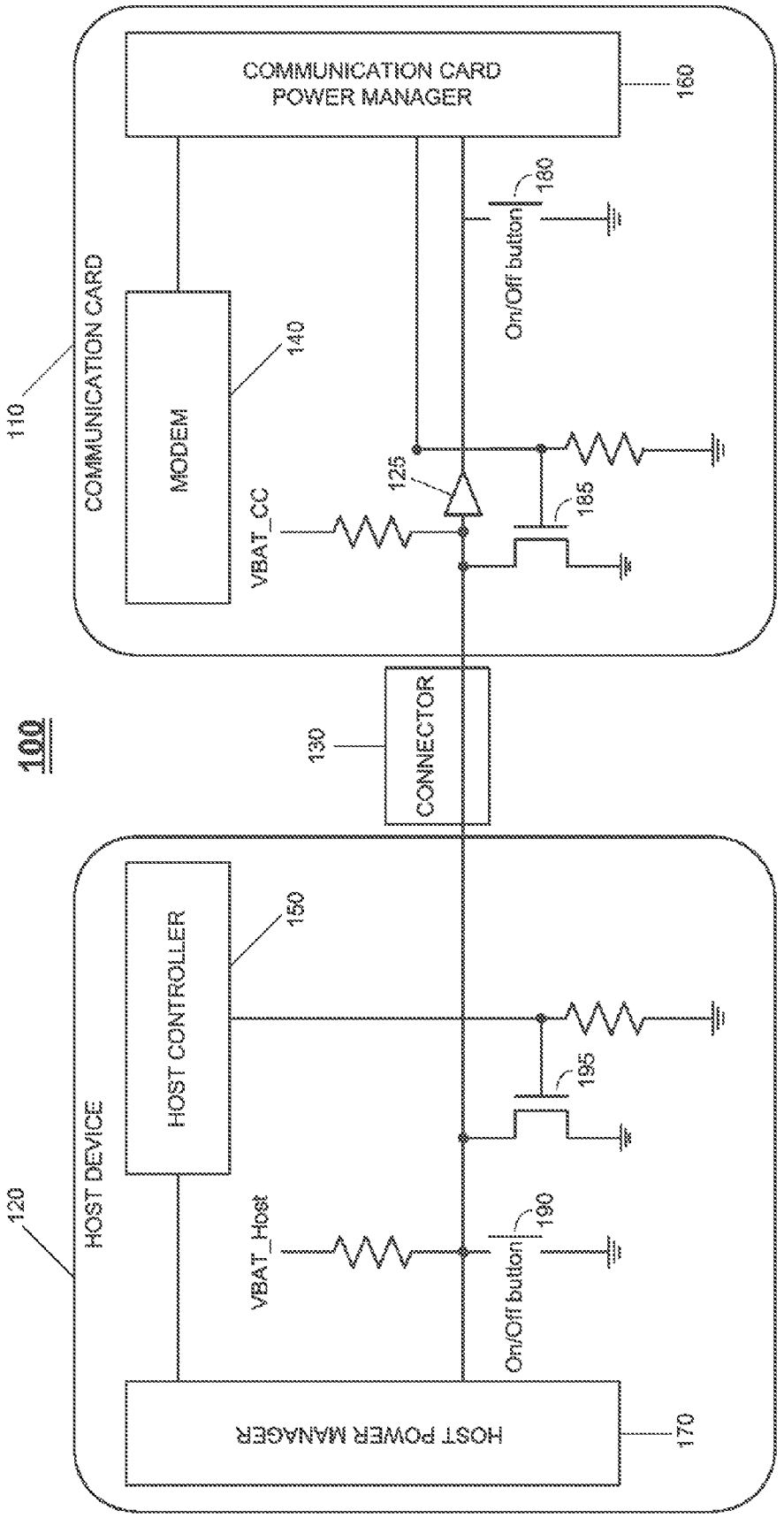

100
110
COMMUNICATION CARD
MODEM
140
COMMUNICATION CARD POWER MANAGER
160
On/Off button
180
VBAT_CC
125
185
130
CONNECTOR
120
HOST DEVICE
HOST CONTROLLER
150
195
VBAT_Host
190
On/Off button
HOST POWER MANAGER
170

FIG. 1A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HOST POWER MANAGER
170

FIG. 1B

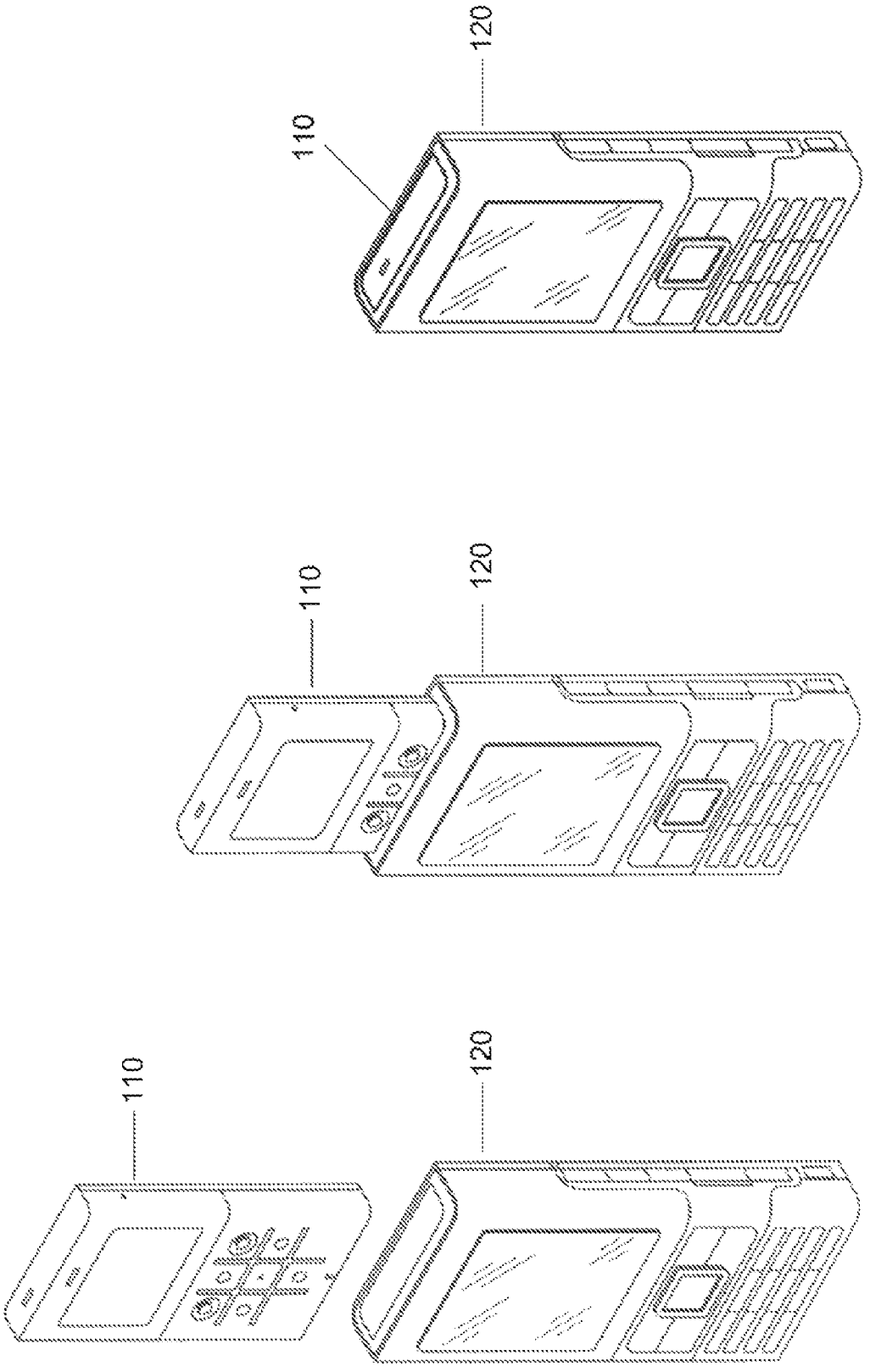

FIG. 2

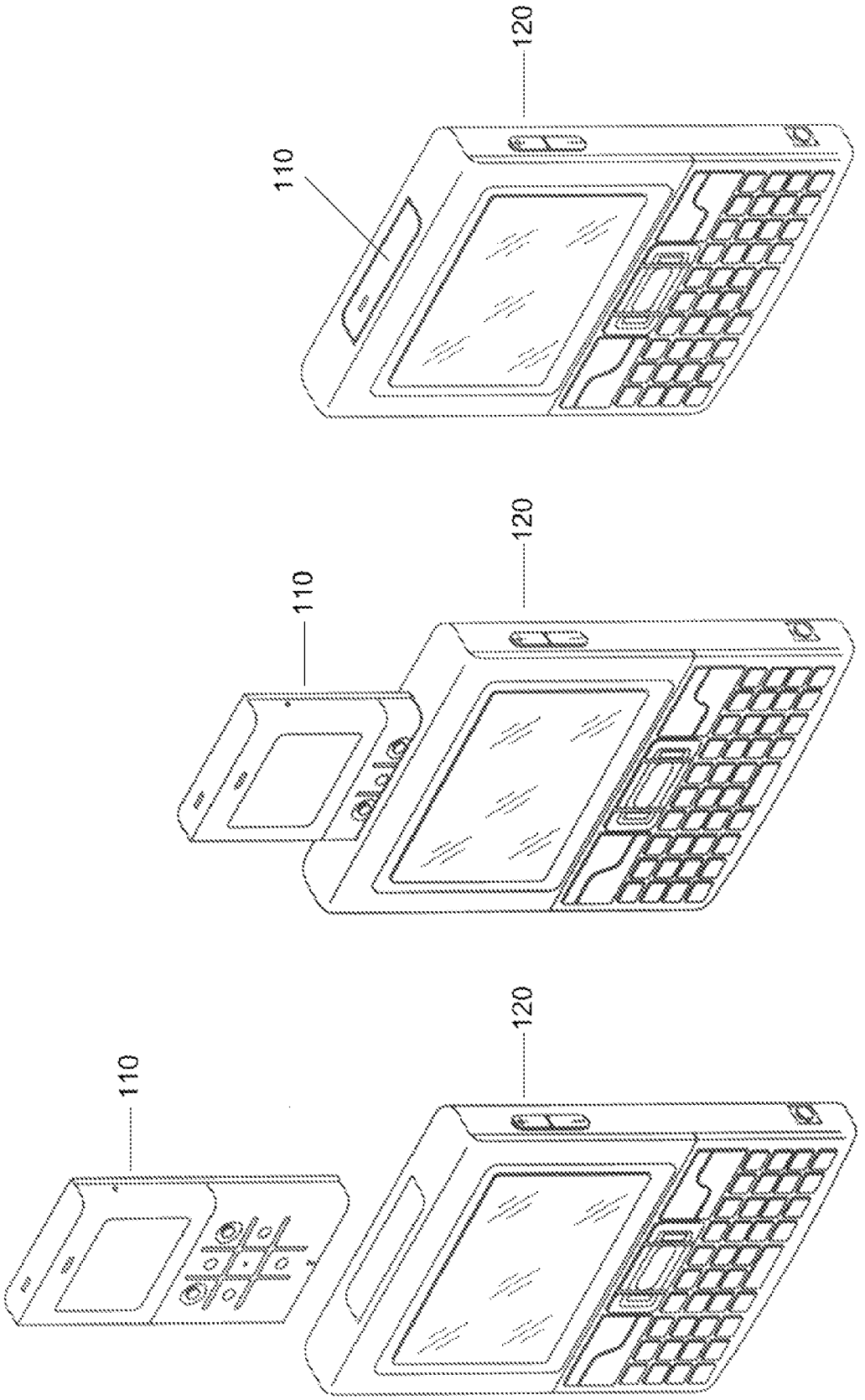

FIG. 3

BI-DIRECTIONAL POWER CONTROL

FIELD OF THE INVENTION

The field of the present invention is power management and control for electronic devices.

BACKGROUND OF THE INVENTION

Today's mobile devices are designed to optimize their power consumption, and specifically to avoid power loss during standby or shutdown. Generally, silicon integrated circuits (ICs) have significant current leakage, which is consumed when they are connected to a power source, even if they are not operational. To mitigate the leakage, mobile devices include a power management IC that controls the power to other ICs in the device, and cuts off power to the other ICs when the device is in standby or shutdown mode. Detection of a wakeup event by the power management IC, serves to power the device on or off. A wakeup event is either a button press and release, or a switch being closed and released thereby changing its logical level from 1 to 0 and back to 1.

SUMMARY OF THE DESCRIPTION

Aspects of the present invention relate to a mobile communication card which connects to another electronic device, where the other electronic device may be a host device that interoperates with the communication card, or a jacket for the communication card, the jacket being a passive device that does not operate independently of the communication card. A single line of a connector between the communication card and the jacket/host suffices to enable the communication card to turn the jacket/host on and off, and to enable the jacket/host to turn the communication card on and off. The same line is used for the communication card to generate wakeup events to power the jacket/host on or off, and for the jacket/host to generate wakeup events to power the communication card on or off. A wakeup event is either a button press and release, or a switch being closed and released thereby changing its logical level from 1 to 0 and back to 1.

There is thus provided in accordance with an embodiment of the present invention an electrical circuit for bi-directional power control between two devices, including a first battery-operated device, including a first battery for providing a source of power to the first battery-operated device, a first power management subsystem connected to the first battery, to power on and power off components of the first battery-operated device in response to a first wakeup event, WE_1, and a first on/off button for generating WE_1, a second battery-operated device, including a second battery for providing a source of power to the second battery-operated device, a second power management subsystem connected to the second battery, to power on and power off components of the second battery-operated device in response to a second wakeup event WE_2, a second on/off button for generating WE_2, and a switch for generating WE_1 simultaneously when the second on/off button generates WE_2, and circuitry including a single connection inter-connecting the first power management subsystem, the first on/off button, the second power management subsystem, the second on/off button, and the switch for generating WE_1.

There is further provided in accordance with an embodiment of the present invention an electrical circuit for bi-directional power control between two devices, including a mobile communication card, an electronic device that connects to the communication card, the electronic device being either (i) a host device that operates independently of the communication card and also interoperates with the communication card, or (ii) a jacket for the communication card, wherein the jacket is a passive device that does not operate independently of the communication card, and circuitry connecting the mobile communication card with the electronic device, including a card on/off button for the mobile communication card, a device on/off button for the electronic device, and a switch, wherein the circuitry uses a single connection line connecting the communication card, the electronic device, the card on/off button, the device on/off button, and the switch, to enable (i) the card on/off button to power the communication card on and off, (ii) the device on/off button to power the electronic device on and off, and (iii) the electronic device to simultaneously power the communication card on and off via the switch when the electronic device is powered on and off by the device on/off button.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more fully understood and appreciated from the following detailed description, taken in conjunction with the drawings in which:

FIGS. **1**A and **1**B are simplified diagrams of circuits that provide bi-directional power control, in accordance with an embodiment of the present invention;

FIG. **2** is an illustration of communication card being inserted into a jacket, in accordance with an embodiment of the present invention; and

FIG. **3** is an illustration of communication card being inserted into a host, in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

Aspects of the present invention relate to power management and control between two connected electronic devices. Using special circuitry, each device is able to turn the other device on and off, by generating wakeup events at one device to power the other device on or off, over a single line of a connector.

Reference is now made to FIGS. **1**A and **1**B, which are simplified diagrams of circuits **100** that provide bi-directional power control, in accordance with an embodiment of the present invention. Shown in FIGS. **1**A and **1**B is a communication card **110** connected to a device **120** via a dedicated connector **130**. Communication card **110** is a mobile communication device that includes a modem **140**. Communication card **110** attaches to device **120** via connector **130**.

Device **120** may be a passive device, referred to as a "jacket", which does not operate independently of communication card **110**. In this regard, reference is now made to FIG. **2**, which is an illustration of communication card **110** being inserted into a jacket **120**, in accordance with an embodiment of the present invention.

Device **120** may alternatively be an active device, referred to as a "host", which has its own controller **150** and can operate independently of communication card **110**. In this regard, reference is now made to FIG. **3**, which is an illustration of communication card **110** being inserted into a host **120**, in accordance with an embodiment of the present invention. The devices **120** shown in FIGS. **1**A and **1**B are host devices, but it will be appreciated by those skilled in the art that the circuits of FIGS. **1**A and **1**B also apply to jacket devices.

In an embodiment of the present invention, communication card **110** and host **120** are battery-operated devices, and have their own batteries for power. Power sources for communication card **110** and host **120** are designated by VBAT_CC and VBAT_Host, respectively, in circuit **100**. Typical voltages for the batteries range from 4.2V for a fully charged battery to 2.8V-3.2V for a low battery, depending on system characteristics. Circuit **100** uses an optional voltage level shifter **125** to control the potential voltage gap between power sources VBAT_CC and VBAT_Host. One of the device batteries may be fully charged at 4.2V, for example, and the other may be at the low range of 3.2V.

Voltage level shifter **125** is powered from VBAT_CC, and its output level is based on VBAT_CC. Specifically, logical bit **1** corresponds to an output of VBAT_CC, and logical bit **0** corresponds to an output level of zero voltage. Voltage level shifter **125** also manages I/O levels of communication card **110**, which may differ from the level VBAT_CC.

Circuit **100** includes grounds to protect the I/O units of the two devices from exposure to a high supply voltage, and to protect the devices' power sources from being shorted to one another.

Communication card **110** and host **120** are assumed to have respective power management ICs **160** and **170** that power them on and off when wakeup events occur. Additionally, a single line of connector **130** between communication card **110** and host **120** enables each device to generate wakeup events to power the other device on and off.

Communication card **110** and host **120** may be powered on and off independently; i.e., communication card **110** is able to be turned on when host **120** is turned on or off, and host **120** is able to be turned on when communication card **110** is turned on or off. Moreover, circuit **100** of FIG. **1** enables communication card **110**, when it is turned on, to turn host **120** on and off; and enables host **120**, when it is turned on, to turn communication card **110** on and off.

According to an embodiment of the present invention, host **120** includes an internal watchdog timer, which is used to turn on communication card **110** after a predetermined period of time.

Circuit **100** includes two on/off buttons, **180** and **190**, and two on/off switches, **185** and **195**, which cause each of communication card **110** and host **120** to power the other on or off. Buttons **180** and **190** are physical buttons that can be activated by a user.

Switches **185** and **195** are electronic switches that are inaccessible to the user. Instead, as shown in FIG. **1**A, switches **185** and **195** are controlled by modem **140** and host controller **150**, respectively. Alternatively, as shown in FIG. **1**B, switch **185** may be controlled by communication power manager **160**, where power manager **160** receives its commands from modem **140**.

Switch **195** is generally present on host devices **120** and not on jacket devices, since host devices operate in standalone mode independently of communication card **110**, whereas jacket devices do not operate in standalone mode.

Circuit **100** provides simultaneous and non-simultaneous power on/off control. Use of switch **185** to turn host **120** on or off, does not affect regular operation of communication card **110** and, vice versa, use of switch **195** to turn communication card **110** on or off, does not affect regular operation of host **120**.

Specifically, when operating alone, communication card **110** is turned on and off by button **180**. When button **180** is pressed to turn on communication card **110**, a wakeup event is detected in its power management system **160**. When communication card **110** is attached to host **120**, button **180** is generally physically inaccessible, and communication card **110** can only be turned on simultaneously with host **120**, via switch **185** using the internal watchdog timer, button **190** or switch **195**.

Similarly, when operating alone, host **120** is turned on and off by button **190**. When button **190** is pressed to turn on host **120**, a wakeup event is detected in its power management system **170**. When communication card **110** is attached to host **120**, host **120** can be turned on asynchronously by button **190**, and can also be turned on synchronously with communication card **110**, via switch **195**.

If device **120** is a jacket device, instead of a host device, communication card **110** is turned on and off via switch **195** on jacket **120**, which generates a wakeup event for power management system **160**.

Power off events are generally reported to modem **140** and to host controller **150** before each respective device is turned off. In an embodiment of the present invention, when button **190** is used to turn off one or both of communication card **110** and host **120**, button **190** must be pressed for a long press. The time duration of a press of button **190** is calculated in software, by host controller **150**, generally via telemetries that controller **150** receives from host power manager **170**.

Similarly, when communication card **110** is not attached to host **120**, button **180** is accessible, and may be used to turn communication card **110** on and off. The time duration of a press of button **180** is calculated in software, by card modem **140**, generally via telemetries that modem **140** receives from host power manager **160**.

TABLE I summarizes an embodiment of simultaneous and non-simultaneous power on/off control enabled by button **190**, and switches **185** and **195**, when communication card **110** is attached to host **120**.

TABLE I

Power on/off control when communication card 110 is attached to host 120

Before wakeup/shutdown event			After wakeup/shutdown event	
Host (120) State	Communication card (110) state	Wakeup/shutdown event	Host (120) State	Communication card (110) state
Off	Off	Button 190 pushed	On	On
On	Off	Switch 195 activated	On	On
		Button 190 pushed	Off	Off
Off	On	Button 190 pushed	On	On
On	On	Switch 195 activated	On	Off
		Button 190 pushed	Off	Off

TABLE I indicates that when switch **195** is activated to turn off communication card **110**, host device **120** remains on. In such case host device **120** turns itself off in a different manner, as appropriate, not using switch **195**.

Circuit **100** uses voltage level shifter **125** to manage the potential voltage gap between I/Os of the two devices.

An advantage of circuit **100** is that it uses a single line of a connector between communication card **110** and jacket/host **120**, for carrying wakeup signals.

In reading the above description, persons skilled in the art will realize that there are many apparent variations that can be applied to the circuit described. In particular, it will be appreciated that some power management systems have two input signals for waking up a device. In such case, the on/off button of a device may be connected to one of its power management

inputs, with the other power management input being used for a remote wakeup signal coming from another device.

In the foregoing specification, the invention has been described with reference to specific exemplary embodiments thereof. It will, however, be evident that various modifications and changes may be made to the specific exemplary embodiments without departing from the broader spirit and scope of the invention as set forth in the appended claims. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense.

What is claimed is:

1. An electrical circuit for bi-directional power control between two devices, comprising:

a first battery-operated device, comprising:

a first battery operative to provide a source of power to the first device;

a first power management subsystem connected to said first battery, operative to power on components of the first device in response to occurrence of an event to wake up the first device; and

a first on/off button operative to generate an event to wake up the first device;

a second battery-operated device, comprising:

a second battery operative to provide a source of power to the second device;

a second power management subsystem connected to said second battery, operative to power on components of the second device in response to occurrence of an event to wake up the second device;

a second on/off button operative to generate an event to wake up the second device; and

a switch operative to automatically generate an event to wake up the first device, in response to said second on/off button generating an event to wake up the second device; and

circuitry comprising a single connection line inter-connecting said first power management subsystem, said first on/off button, said second power management subsystem, said second on/off button, and said switch.

2. The circuit of claim **1** wherein said second device remains operational when said first device is powered off.

3. The circuit of claim **1** wherein said first device further comprises a switch operative to automatically generate an event to wake up the second device, in response to said first on/off button generating an event to wake up the first device, and wherein said single connection line also inter-connects said second device switch with said first and said second power management subsystems, said first and said second on/off buttons, and said first device switch.

4. The circuit of claim **1** wherein said first device further comprises a voltage level shifter operative to shift an I/O level of said first device to a voltage level of its battery.

5. An electrical circuit for bi-directional power control between two devices, comprising:

a mobile communication card;

an electronic device that connects to said communication card, the electronic device being either (i) a host device that operates independently of said communication card and also interoperates with said communication card, or (ii) a jacket for said communication card, wherein the jacket is a passive device that does not operate independently of said communication card; and

circuitry connecting said mobile communication card with said electronic device, comprising:

a card on/off button operative to power said mobile communication card on and off;

a device on/off button operative to power said electronic device on and off; and

a switch,

wherein said circuitry uses a single connection line connecting said communication card, said electronic device, said card on/off button, said device on/off button, and said switch, to enable (i) said card on/off button to power said communication card on and off, (ii) said device on/off button to power said electronic device on and off, and (iii) said electronic device to automatically power said communication card on and off using said switch, in response to said electronic device being respectively powered on and off.

6. The circuit of claim **5** wherein said communication card comprises a card power management subsystem that powers said communication card on in response to a card wakeup event, and wherein said electronic device comprises a device power management subsystem that powers said electronic device on in response to a device wakeup event.

7. The circuit of claim **5** further comprising an auxiliary switch, and wherein said circuitry also uses the single connection line to enable (iv) said communication card to automatically power said electronic device on and off using said auxiliary switch, in response to said communication card being respectively powered on and off.

8. An electrical circuit for bi-directional power control between two devices, comprising:

a first electronic device, comprising:

a first power management subsystem, operative to power on components of the first device in response to occurrence of an event to wake up the first device; and

a first switch operative to generate an event to wake up a second electronic device;

a second electronic device, comprising:

a second power management subsystem, operative to power on components of the second device in response to occurrence of an event to wake up the second device; and

a second switch operative to generate an event to wake up the first device; and

circuitry inter-connecting said first power management subsystem, said first switch, said second power management subsystem, and said second switch.

9. The circuit of claim **8** wherein said first electronic device further comprises a timer, operative to activate said first switch after lapse of a predetermined period of time.

10. The circuit of claim **8** wherein said second electronic device is a communication card.

11. The circuit of claim **10** wherein said first electronic device is a host device that operates independently of said communication card and also interoperates with said communication card.

12. The circuit of claim **10** wherein said first electronic device is a jacket for said communication card, wherein the jacket is a passive device that does not operate independently of said communication card.

* * * * *