

METHOD AND APPARATUS FOR DETERMINING BATTERY STATUS TO OPERATE A PORTABLE ELECTRONIC DEVICE

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Field of the Invention

This invention relates in general to electronic devices powered by batteries and in particular to a method and apparatus for determining battery status to operate a portable electronic device.

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Background of the Invention

Portable electronic devices are typically powered by batteries that have limited power content. When power available from such batteries is depleted to a level that is insufficient to maintain operation of the portable electronic devices, replacement of the batteries with new or recharged batteries becomes necessary.

Knowing the power content remaining in batteries of portable electronic devices, such as handheld computers and personal digital assistants (PDAs), helps to prevent loss of data due to weak batteries. Weak batteries can also adversely corrupt data already stored within the portable electronic devices. Hence, to prevent data loss or corruption, batteries used in such portable electronic devices need constant monitoring to ensure sufficient power is available for reliable operation.

Furthermore, when new or recharged batteries replace depleted batteries, a portable electronic device needs to be certain of sufficient power available in the new or recharged batteries before resuming operations. Unknowingly resuming operations of the portable electronic device with weak or uncharged batteries can cause the portable electronic device to malfunction especially during its powering up when its initial operating parameters are set.

Thus, a need exists for determining battery status to operate a portable electronic device and, thereby, prevent problems resulting from weak batteries, such as data loss or corruption.

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Summary of the Invention

In carrying out the objects of the present invention in one form, there is provided a method for determining battery status to operate a portable
5 electronic device wherein the portable electronic device is powered by at least one battery and includes a microcontroller for controlling its operations according to the battery status. The method comprises the step of detecting an interrupt request generated by an interrupt signaller within the portable electronic device in response to a change of the battery status
10 from one of a plurality of predetermined battery conditions to another one of the plurality of predetermined battery conditions wherein the plurality of predetermined battery conditions includes at least three predetermined voltage ranges, removal of the at least one battery, and replacement of the at least one battery. The method further comprises the step of activating or
15 deactivating at least one of a plurality of control signals to control the battery monitor and the portable electronic device in response to the change. The step of activating or deactivating comprises at least the step of resetting the battery monitor upon detecting the interrupt request indicating the replacement of the at least one battery after the removal of the at least
20 one battery.

Brief Description of the Drawings

25 FIG. 1 is a functional block diagram of a portable electronic device in accordance with a preferred embodiment of the present invention.

FIG. 2 is a circuit schematic of a battery monitor within the portable electronic device of FIG. 1 in accordance with the preferred embodiment of
30 the present invention.

FIG. 3 is a flow chart showing a method of operation of a microcontroller shown in FIG. 1 in accordance with the preferred embodiment of the present invention.
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FIG. 4 is a table showing control signals corresponding to battery status in accordance with the preferred embodiment of the present invention.

5 FIG. 5 is a state diagram for determining battery status upon resetting in accordance with the preferred embodiment of the present invention.

Detailed Description of the Invention

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In accordance with a preferred embodiment of the present invention, FIG. 1 shows a functional block diagram of a portable electronic device 100 having a microcontroller 108 for controlling operations and operating with at least one battery 104 supported by at least one back-up battery 114. The portable electronic device 100 comprises an interrupt signaller 106 for
15 generating interrupt requests to the microcontroller 108 and a battery monitor 102 for monitoring the at least one battery 104 to determine battery status according to a plurality of predetermined battery conditions. The plurality of predetermined battery conditions includes at least three
20 predetermined voltage ranges, removal of the at least one battery 104, and replacement of the at least one battery 104. The at least three predetermined voltage ranges includes a first voltage range, a second voltage range, and a third voltage range for classifying voltage of the at least one battery 104.

25 In accordance with the preferred embodiment of the present invention, the battery monitor 102 in FIG. 1 comprises a voltage indicator 110 and a battery presence indicator 112. The voltage indicator 110 and the battery presence indicator couple to the at least one battery 104, the interrupt signaller 106, and the microcontroller 108.

30 Determining the plurality of predetermined battery conditions advantageously enables the portable electronic device 100 to operate efficiently according to the battery status of the at least one battery 104. Hence, for example, when voltage of the at least one battery 104 drops from continuing use, the microcontroller 108 then controls the portable
35 electronic device 100 to operate according to the battery status of the at least one battery 104 accordingly. As such, data loss or corruption can be

prevented by having the portable electronic device activate or deactivate certain functions to protect against the data loss or corruption.

In accordance with the preferred embodiment of the present invention, FIG. 2 is a circuit schematic of the battery monitor 102. A plurality of control signals from the microcontroller 108 controls the voltage indicator 110 and the battery presence indicator 112. Two of the plurality of control signals, $\overline{\text{MB_Low}}$ and $\overline{\text{MB_Fatal}}$, control transistors 240, 242 in the voltage indicator 110. Another one of the plurality of control signals, MB_Out , controls the battery presence indicator 112.

In accordance with the preferred embodiment of the present invention, the battery monitor 102 operates when, coupled with the at least one battery 104, the portable electronic device 100 is powered on with a supply rail of voltage V_s . Thereafter, the battery monitor 102 starts to monitor the at least one battery 104 according to the plurality of predetermined battery conditions. In accordance with the preferred embodiment of the present invention, the first voltage range indicates that the voltage of the at least one battery 104 is healthy. Values of resistors 202, 204 are selected such that voltage comparator 250 will trigger when voltage at V_1 is less than reference voltage V_{REF} . Triggering of the voltage comparator 250 occurs when the at least battery 104 changes its voltage level from the first voltage range to the second voltage range. The triggering sets off the interrupt signaller 106 that then sends an interrupt request, $\overline{\text{IRQ}}$, to the microcontroller 108. Upon receiving the interrupt request, the microcontroller 108 then activates $\overline{\text{MB_Low}}$ to turn on transistor 240.

Turning on transistor 240 sets up monitoring of the at least one battery 104 to detect changes of its voltage level from the second voltage range to the third voltage range. Resistor 208 has a value such that the voltage at V_1 is less than V_{REF} when the voltage level of the at least one battery 104 changes from the second voltage range to the third voltage range and triggers the voltage comparator 250 to send an interrupt request to the microcontroller 108. The microcontroller 108, upon receiving this interrupt request, activates $\overline{\text{MB_Fatal}}$ to turn on transistor 242. Thereafter, with the voltage level of the at least one battery 104 in the third voltage range, the battery monitor 102 is now set to detect removal of the at least one battery 104. To save on current consumption when the battery monitor 102 is monitoring the at least one battery 104 in the third voltage range, the microcontroller 108 turns off transistor 240 by deactivating $\overline{\text{MB_Low}}$.

In accordance with the preferred embodiment of the present invention, the removal of the at least one battery 104 is detected by the battery presence indicator 112 and causes voltage at V_B to increase towards voltage V_s . When the voltage at V_B reaches a value such that transistor 246
5 is turned off, the interrupt signaller 106 will once again be triggered to generate an interrupt request to the microcontroller 108. With this interrupt request, the microcontroller 108 activates MB_Out to turn on transistor 244. Thereafter, the battery monitor 102 is now ready to detect the replacement of the at least one battery 104.

10 In accordance with the preferred embodiment of the present invention, the replacement of the at least one battery 104 is detected by the battery monitor 102 when a new at least one battery is placed into the portable electronic device 100. For rechargeable batteries, the replacement of the at least one battery 104 includes replacing the at least one battery 104 upon
15 recharging. Resistors 210,216 have values such that the replacement of the at least one battery 104 with the new at least one battery, or with the at least one battery 104 upon recharging, causes the voltage at V_B to drop to a value that will trigger the voltage comparator 250. When triggered, the voltage comparator 250 activates the interrupt signaller 106 to generate an
20 interrupt request to the microcontroller 108. Receiving this interrupt request, the microcontroller 108 resets the battery monitor 102 to determine the battery status of the new at least one battery.

In resetting the battery monitor 102, the microcontroller 108 polls the battery monitor 102 to determine the battery status of the at least one
25 battery 104 after its replacement. In polling, the microcontroller 108 first sets the battery monitor 102 to detect any interrupt request from the interrupt signaller 106 so as to determine whether the at least one battery 104 is in a battery healthy state. The battery healthy state corresponds to a voltage of the at least one battery 104 within the first voltage range. When
30 no interrupt request is detected, the at least one battery 104 is thereby determined to be in the battery healthy state. However, when an interrupt request is detected, the microcontroller 108 sets the battery monitor 102 to monitor the at least one battery in a battery low state. The battery low state corresponds to a voltage of the at least one battery 104 within the second
35 voltage range. Continuing this process to determine the battery status of the at least one battery 104, the microcontroller 108 polls the interrupt signaller 106 again. Thereafter, a subsequent interrupt request will trigger

the microcontroller 108 to set the battery monitor 102 to a battery fatal state that corresponds to a voltage of the at least one battery 104 within the third voltage range. Otherwise, the at least one battery 104 is determined to be in the battery low state. Hence, in resetting the battery monitor 102, the
 5 microcontroller 108 polls the interrupt signaller 106 and sequentially determines the battery status of the at least one battery 104.

Polling the interrupt signaller 106 advantageously enables the microcontroller 108 in the present invention to check on the battery status of the at least one battery 104 after its replacement. This prevents power up
 10 of the portable electronic device 100 when the at least one battery 104 is weak or faulty. Hence, data loss or corruption resulting from inadvertent usage of weak or faulty batteries is effectively prevented.

FIG. 3 is a flow chart showing a method 300 of operation of the microcontroller 108, in accordance with the preferred embodiment of the
 15 present invention. Starting at step 302, the method 300 then continues with the microcontroller 108 detecting interrupt requests from the interrupt signaller 106 at step 304. The interrupt requests are generated by the interrupt signaller 106 when the at least one battery 104 changes from one of the at least three predetermined voltage ranges to another one of the at
 20 least three predetermined voltage ranges and triggers the voltage comparator 250. When an interrupt request is detected at step 306, the method continues to step 308 for activating or deactivating at least one of the plurality of control signals by the microcontroller 108.

FIG. 4 is a table showing control signals corresponding to battery
 25 status in accordance with the preferred embodiment of the present invention. The first voltage range, the second voltage range, and the third voltage range, corresponds to the at least one battery 104 in the battery healthy state, the battery low state, and the battery fatal state, respectively.

FIG. 5 is a state diagram for determining battery status upon resetting
 30 in accordance with the preferred embodiment of the present invention. By polling the interrupt signaller 106, the microcontroller 108 determines the voltage of the at least one battery 104. Consistency in the voltage of the at least one battery 104 is also determined before the microcontroller 108 activates or deactivates the plurality of
 35 control signals to control the portable electronic device 100 and the battery monitor 102. Throughout this resetting, the at least one back-up battery 114

provides power until the battery status of the at least one battery 104 is determined.

5 In the present invention, the battery status of the at least one battery 104 is advantageously monitored throughout its use. Unlike conventional methods in the prior art, monitoring of the at least one battery 104 in the present invention extends beyond merely determining whether the at least one battery 104 is strong or weak. In addition to detecting the removal and replacement of the at least one battery 104, the battery monitor 102 in the present invention also checks the battery status of any new at least one
10 battery 104 before enabling the portable electronic device 100 to fully operate. This prevents operation of the portable electronic device 100 when weak or faulty batteries are inadvertently used.

By now it should be appreciated that there has been provided a novel method and apparatus for determining battery status to operate a portable
15 electronic device 100.

We claim:



CLAIMS

1. A portable electronic device operating with at least one battery and having a microcontroller for controlling operations of the portable electronic device in response to an interrupt request, the portable electronic device comprising:
- 5 an interrupt signaller for generating the interrupt request; and
a battery monitor for monitoring the at least one battery to
determine battery status according to at least three predetermined
10 voltage ranges including a first voltage range, a second voltage
range, and a third voltage range, the battery monitor comprising:
a voltage indicator, coupled to the at least one battery and
to the interrupt signaller, for activating the interrupt signaller
to generate the interrupt request when the at least one battery
15 changes from the first voltage range to the second voltage
range or from the second voltage range to the third voltage
range.
2. The portable electronic device of Claim 1 wherein the battery
20 monitor further comprises a battery presence indicator for detecting
removal of the at least one battery and activating, thereafter, the interrupt
signaller to generate the interrupt request and further wherein the battery
presence indicator couples to the voltage indicator, the interrupt signaller,
and the at least one battery.
- 25 3. The portable electronic device of Claim 2 wherein the battery
presence indicator couples to a new at least one battery and activating,
thereafter, the interrupt signaller to generate the interrupt request when the
new at least one battery is detected.
- 30 4. The portable electronic device of Claim 2 wherein the battery
presence indicator couples to the at least one battery and activating,
thereafter, the interrupt signaller to generate the interrupt request after
detecting replacement of the at least one battery.
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5. A battery monitor for determining battery status of at least one battery supplying power to a portable electronic device wherein the portable electronic device includes a microcontroller for controlling operations of the portable electronic device and an interrupt signaller for generating an interrupt request to the microcontroller when activated, the
5 battery monitor comprising:

10 a voltage indicator, coupled to the at least one battery and to the interrupt signaller, for activating the interrupt signaller when the at least one battery changes from one of at least three predetermined voltage ranges to another one of the at least three predetermined voltage ranges.

6. The battery monitor of Claim 5 further comprising a battery presence indicator for detecting removal of the at least one battery and
15 activating, thereafter, the interrupt signaller to generate the interrupt request and further wherein the battery presence indicator couples to the voltage indicator, the interrupt signaller, and the at least one battery.

7. The battery monitor of Claim 6 wherein the battery presence
20 indicator couples to a new at least one battery and activating, thereafter, the interrupt signaller to generate the interrupt request when the new at least one battery is detected.

8. The battery monitor of Claim 6 wherein the battery presence
25 indicator couples to the at least one battery and activating, thereafter, the interrupt signaller to generate the interrupt request after detecting replacement of the at least one battery.

9. The battery monitor of Claim 5 wherein the at least three
30 predetermined voltage conditions comprises a first voltage range, a second voltage range, and a third voltage range.



10. A method for determining battery status to operate a portable electronic device wherein the portable electronic device is powered by at least one battery and includes a microcontroller for controlling its operations according to the battery status, the method comprising the steps of:

5 detecting an interrupt request generated by an interrupt signaller within the portable electronic device in response to a change of the battery status from one of at least three predetermined voltage ranges to another one of the at least three predetermined voltage ranges wherein the at least
10 three predetermined voltage ranges includes a first voltage range, a second voltage range, and a third voltage range; and

thereafter, activating or deactivating at least one of a plurality of control signals to control a battery monitor within the portable electronic
15 device in response to the change of the battery status.

11. The method of Claim 10 wherein the step of activating or deactivating comprises the step of resetting the battery monitor after replacement of the at least one battery with a new at least one battery or
20 the at least one battery upon recharging.

12. The method of Claim 11 wherein the step of resetting comprises the step of determining the battery status of the new at least one battery or the at least one battery.

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13. The method of Claim 12 wherein the step of determining comprises the step of polling the interrupt signaller and sequentially activating or deactivating at least one of the plurality of control signals to check the battery status of the new at least one battery or the at least one
30 battery according to the at least three predetermined voltage ranges.



14. A method for determining battery status to operate a portable electronic device wherein the portable electronic device is powered by at least one battery and includes a microcontroller for controlling its operations according to the battery status, the method comprising the steps of:

5 detecting an interrupt request generated by an interrupt signaller within the portable electronic device in response to a change of the battery status from one of a plurality of predetermined battery conditions to another one of the plurality of predetermined battery conditions wherein the
10 plurality of predetermined battery conditions includes at least three predetermined voltage ranges, removal of the at least one battery, and replacement of the at least one battery;

and

15 activating or deactivating at least one of a plurality of control signals to control a battery monitor within the portable electronic device in response to the change wherein the step of activating or deactivating comprises at least the step of:

20 resetting the battery monitor upon detecting the interrupt request indicating the replacement of the at least one battery after the removal of the at least one battery.

15. The method of Claim 14 wherein the step of resetting comprises the step of determining the battery status of the at least one battery after the replacement of the at least one battery.

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16. The method of Claim 15 wherein the step of determining comprises the steps of:

30 polling the interrupt signaller and sequentially activating or deactivating the at least one of the plurality of control signals to determine voltage of the at least one battery according to the at least three predetermined voltage ranges; and

thereafter, setting the battery monitor and the portable electronic device to operate according to the voltage.