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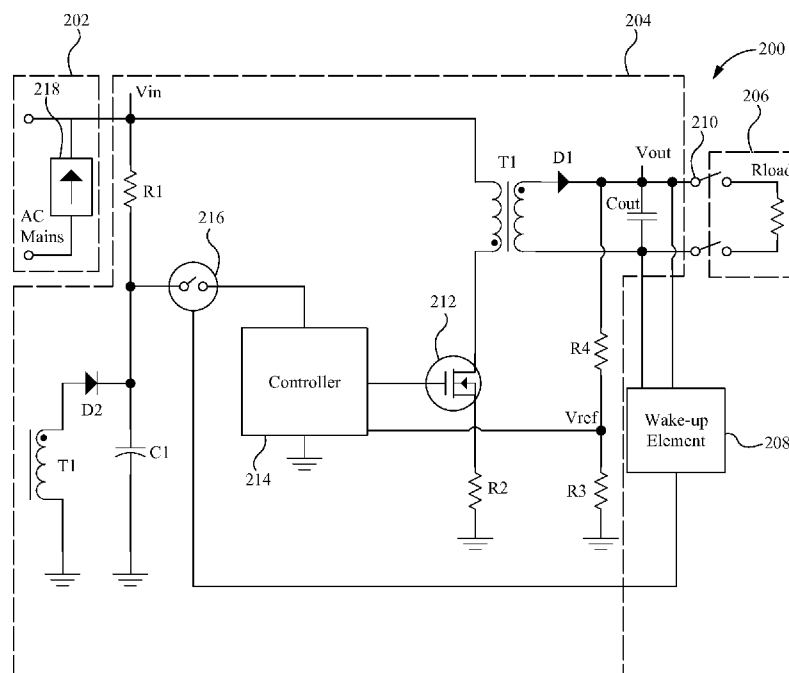
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(57) Abstract: A power converter system, method and device powers a load when coupled to the load and draws a quasi-zero amount of power from the power supply when not coupled to the load. The power converter system maintains an output voltage such that the power converter system is able to properly "wake-up" when a load is coupled by intermittently operating the power converter for a preselected number of cycles when it is detected that the output voltage has fallen below a threshold level.

POWER CONVERTER WITH QUASI-ZERO POWER CONSUMPTION

FIELD OF THE INVENTION

_____The present invention relates to the field of power supplies. More particularly, the present invention relates to a power converter system with a quasi-zero power consumption feature.

BACKGROUND

Previously, restrictions on power converter efficiency centered around the efficiency at which the power converter is able to transfer the power received from the mains to the load for consumption. Recently however, greater restrictions have been introduced centering on the efficiency of power converters when no load is present. In particular, this efficiently relates to how much power is consumed by chargers when the device to be charged is disconnected and when cell phones, set top boxes, laptops and other electronic devices are in standby or sleep modes. Thus far, this type of efficiency has been problematic to achieve because it is difficult to design a power converter that does not use much power when a load is not connected, but is able to properly “wake-up” and provide the needed power when a load is connected.

SUMMARY OF THE INVENTION

A power converter system, method and device powers a load when coupled to the load and draws a quasi-zero amount of power from the power supply when not coupled to the load. The power converter system maintains an output voltage such that the power converter system is able to properly “wake-up” when a load is coupled by intermittently operating the power converter for a preselected number of cycles when it is detected that the output voltage has fallen below a threshold level. The small ratio of operation time required to recharge the output voltage compared to the time required for the output voltage to decay enables the power converter system to operate according to an almost or quasi-zero duty cycle. As a result, the efficiency of the power converter when not connected to the load is maximized.

One aspect of the present invention is directed to a power converter system for

powering a load when coupled to the load and for drawing a quasi-zero amount of power when not coupled to the load. The system comprises a power supply for supplying an input power, a power converter coupled with the power supply, wherein the power converter produces an output voltage from the input power and a wake-up element coupled to the power converting element, wherein when the load is disconnected from the power converter and the output voltage drops below a threshold voltage the wake-up element causes the power converter to recharge the output voltage to a predefined sleep voltage. The power converter is a switch mode power supply having a switching signal comprising one or more cycles, wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage. In some embodiments, the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate until the wake-up element detects that the output voltage equals the predefined sleep voltage. In some embodiments, the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate for a predetermined number of the switching signal cycles. In some embodiments, the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load. In some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles. In some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while keeping the output voltage above the threshold voltage. In some embodiments, the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage. In some embodiments, the power converter and the wake-up element are a part of a single integrated circuit.

A second aspect of the present invention is directed to a power converter device for powering a load when coupled to the load and for drawing a quasi-zero amount of power when not coupled to the load. The device comprises a power converter configured to

produce an output voltage from an input power and a wake-up element coupled to the power converter, wherein when the load is disconnected from the power converter and the output voltage drops below a threshold voltage the wake-up element causes the power converter to recharge the output voltage to a predefined sleep voltage. The power converter is a switch mode power supply having a switching signal comprising one or more cycles, wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage. In some embodiments, the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate until the wake-up element detects that the output voltage equals the predefined sleep voltage. In some embodiments, the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate for a predetermined number of the switching signal cycles. In some embodiments, the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load. In some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles. In some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while keeping the output voltage above the threshold voltage. In some embodiments, the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage. In some embodiments, the power converter and the wake-up element are a part of a single integrated circuit.

Another aspect of the present invention is directed to a method of powering a load with a power supply when coupled to the load and for drawing a quasi-zero amount of power from the power supply when not coupled to the load. The method comprises detecting if the load is coupled with a power converter with a wake-up element, detecting an output voltage of the power converter with the wake-up element, transmitting a recharge signal from the wake-up element to the power converter if the load is not coupled with the power converter and the output voltage is below a threshold voltage and recharging the output voltage to a

predefined sleep voltage with the power converter upon receiving the recharge signal. The power converter is a switch mode power supply having a switching signal comprising one or more cycles wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage. In some embodiments, the recharging comprises
5 operating the power converter until the wake-up element detects that the output voltage equals the predefined sleep voltage. In some embodiments, the recharging comprises operating the power converter for a predetermined number of the switching signal cycles. In some embodiments, the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load. In
10 some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles. In some embodiments, the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while
15 keeping the output voltage above the threshold voltage. In some embodiments, the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage. In some embodiments, the power converter and the wake-up element are a part of a single integrated circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a functional block diagram of a power converter system according to some embodiments.

Figure 2 illustrates a circuit diagram of a power converter system according to some
25 embodiments.

Figure 3 illustrates a flowchart of a method of powering a load with a power supply when coupled to the load and for drawing a quasi-zero amount of power from the power supply when not coupled to the load according to some embodiments.

DETAILED DESCRIPTION

In the following description, numerous details and alternatives are set forth for the purpose of explanation. However, one of ordinary skill in the art will realize that the invention can be practiced without the use of these specific details. In other instances, well-known structures and devices are shown in block diagram form in order not to obscure the description of the invention with unnecessary detail.

Embodiments of a power converter system, device and method are described herein. The power converter system, device and method power a load when coupled to the load and draw a quasi-zero amount of power from the power supply when not coupled to the load. The power converter system maintains an output voltage such that the power converter system is able to properly “wake-up” when a load is coupled by intermittently operating the power converter for a preselected number of cycles when it is detected that the output voltage has fallen below a threshold level. The small ratio of operation time required to recharge the output voltage compared to the time required for the output voltage to decay enables the power converter system to operate according to an almost or quasi-zero duty cycle. As a result, the efficiency of the power converter when not connected to the load is maximized.

Figure 1 illustrates a functional block diagram of a power converter system 100 according to some embodiments. As shown in Figure 1, the system 100 comprises a power source 102, a power converter 104, a load 106 and a wake-up element 108. The power source 102 is electrically coupled with the power converter 104 which is able to selectively couple or decouple with the load 106 at a coupling point 110. The wake-up element 108 is electrically coupled between the coupling point 110 and the power converter 104. In some embodiments, two or more of the power converter 104, wake-up element 108 and load 106 are integrated on a single integrated circuit. Alternatively, one or more of the power converter 104, wake-up element 108 and load 106 are able to be on separate integrated circuits.

The power source 102 is able to comprise an AC power source such as a main line or plug outlet. Alternatively, the power source 102 is able to comprise a DC power supply. The power converter 104 is able to comprise a power converter circuit, such as a flyback converter. Alternatively, the power converter 104 is able to comprise other types of circuits that include power converters as are well known in the art. For example, the power converter

104 is able to comprise a forward converter, a push-pull converter, a half-bridge converter, a full-bridge converter and/or other configurations of switch mode power supplies as are well known in the art. The wake-up element 108 is able to comprise a low power consuming voltage sensing circuit that is able to monitor the output voltage V_{out} , and the coupling status of the load 106 and control the operation of the power converter 104 accordingly. The load 106 is able to comprise a mobile phone, laptop, set top box, television or other type of electronic device. The coupling point 110 is able to be a physical coupling point and/or an electronic coupling point. Specifically, in some embodiments the coupling point 110 is a physical coupling point wherein, for example, the load 106 is a cell phone and the power converter 104 and wake-up element 108 comprise a cell phone charger such that the load 106 and the converter 104 are physically coupled and decoupled as the cell phone is coupled and decoupled from the charger. Alternatively, in some embodiments the coupling point 110 is an electronic coupling point wherein, for example, the load 106, the power converter 104 and wake-up element 108 all comprise parts of a laptop computer such that the load 106 and the converter 104 are electronically coupled and decoupled as the laptop is put into and out of a sleep/hibernation mode.

In operation, the power converter 104 draws power from the power source 102 and produces an output voltage V_{out} that is able to be used to power the load 106 when the load 106 is coupled to the power converter 104. The wake-up element 108 monitors whether the load 106 is coupled to the power converter 104 and the output voltage V_{out} . If the wake-up element 108 detects that the load 106 is not coupled to the power converter 104 and the output voltage V_{out} is within a desired range or above a predetermined threshold voltage level, the wake-up element 108 interrupts or stops the normal operation of the power converter 104 in order to prevent the converter 104 from drawing power from the power source. If the wake-up element 108 detects that the load 106 is not coupled to the power converter 104 and the output voltage V_{out} is outside the desired range or below the predetermined threshold voltage level, the wake-up element 108 stops interrupting the operation of the power converter 104 and causes the power converter 104 to run in order to recharge the voltage V_{out} within the desired range and/or above the predetermined threshold. In some embodiments, the wake-up element 108 monitors the value of the output voltage V_{out}

while causing the power converter 104 to recharge the output voltage V_{out} and stops the power converter 104 from the recharging as soon as the value of the output voltage V_{out} reaches a desired wake-up voltage value. Alternatively, the wake-up element 108 is able to be configured to cause the power converter 104 to recharge the output voltage V_{out} for a predetermined wake-up period and to stop the power converter 104 after the wake-up period has elapsed. In particular, the wake-up period is able to be a number of pulse cycles that will result in increasing the value of the output voltage V_{out} a desired voltage amount or to a desired voltage level. Alternatively, the wake-up period is able to be a different length of time. As a result, the system 100 is able to minimize the amount of power consumed from the power source 102 by the power converter 104 when the load 106 is not coupled with the power converter 104. Indeed, because the time required to recharge the output voltage V_{out} is generally orders of magnitude shorter than the time it takes that added voltage to decay from the output voltage V_{out} , the duty cycle of the power converter 104 (e.g. the time the converter 104 is operating compared to the time the converter 104 is not operating) approaches zero. Thus, the system 100 provides the benefit of increased power saving efficiency in no load conditions.

Figure 2 illustrates a schematic diagram of a power converter system 200 according to some embodiments. The schematic diagram is substantially similar to the functional block diagram shown in Figure 1 except the additional details described herein. However, it is understood that alternative schematics are able to be used to implement the functional blocks of Figure 2. As shown in Figure 2, the power converter system 200 comprises a power source 202, a power converter 204 having a coupling point 210, a load 206 and a wake-up element 208. In some embodiments, the system 200 is contained on a single integrated circuit. Alternatively, one or more of the components of the system 200 are able to be separate integrated circuits such that the system 200 is formed by multiple integrated circuits electrically coupled together.

The power source 202 comprises an AC mains power signal that is electrically coupled with a rectifier 218 in order to produce a DC input voltage V_{in} that is electrically coupled to the power converter 204. The load 206 comprises a resistor R_{load} that represents the resistance provided by the load 206. In particular, it is understood that the load 206 is

able to comprise numerous different combination of circuitry that are able to be represented by the resistance of the resistor R_{load} , the details of which are omitted for the sake of brevity. The wake-up element 208 comprises a wake-up circuit that is able to detect the output voltage V_{out} and the coupling status of the load 206 while consuming a minimal amount of power. The power converter 204 comprises a transformer T1, a transistor 212, one or more resistors R1, R2, R3, R4, a controller device 214, one or more capacitors C1, C_{out} , one or more diodes D1, D2 and a power saving element 216. It is understood however, that one or more of the components of the power source 202, the power converter 204, the load 206 and/or the wake-up element 208 are able to be positioned or duplicated on one or more of the other elements 202-210.

A primary end of the transformer T1 is electrically coupled between the input voltage V_{in} received from the power source 202 and the drain terminal of the transistor 212 whose gate terminal is electrically coupled with the controller 214 and source terminal is electrically coupled with ground via the resistor R2. This enables the controller 214 to draw power into the transformer T1 by outputting a transistor control signal to the gate terminal of the transistor 212. One of the secondary ends of the transformer T1 is electrically coupled across the diode D1 and capacitor C_{out} to the coupling point 210 and a second of the secondary ends of the transformer T1 is electrically coupled between ground and the controller 214 via the diode D2 and the power saving element 216. Further, the power saving element 216 is coupled with the input voltage V_{in} and ground via the resistor R1 and the capacitor C1, respectively. As a result, the power drawn into the primary end of the transformer T1 is able to be transferred to the capacitor C_{out} at the coupling point 210 via the first secondary end as well as recycled into the capacitor C1 and the controller 214 via the second secondary end. The controller 214 is electrically coupled with a reference voltage V_{ref} at a node between the resistor R3 and ground, and the resistor R4 and the output voltage V_{out} . The wake-up element 208 is electrically coupled across the output capacitor C_{out} and the coupling point 210 in order to detect the output voltage V_{out} and whether the load 206 is coupled to the power converter 204. The wake-up element 208 is also electrically coupled with the power saving element 216 in order to control the power saving element 216.

In some embodiments, the transformer T1 is a flyback transformer. Alternatively, the

transformer T1 is able to be other types of transformers or load isolating circuitry as are well known in the art. In some embodiments, the transistor 212 is a field effect transistor such as a n-type metal-oxide-semiconductor field-effect transistor (MOSFET). Alternatively, the transistor 212 is able to be other types of transistors or switching circuitry as are well known in the art. In some embodiments, the controller device 214 is a SR-NOR latch flip flop. Alternatively, the controller 214 is able to be other types of flip flops, pulse width modulation circuits or signal logic circuitry able to regulate the duty cycle or operation of the transistor 212 as are well known in the art. In some embodiments, the power saving element 216 comprises an electrically controlled switch. Alternatively, the power saving element 216 is able to comprise other types of electric selectively isolating components or combinations of components as are well known in the art. In some embodiments, the size of the output capacitor C_{out} is in the range of **(IS THERE AN IDEAL SIZE RANGE OF THE OUTPUT CAPACITOR?)**. In some embodiments, the size of the output capacitor C_{out} is selected based on charge decay time such that the length of the decay period between a starting voltage and the threshold voltage is maximized. Alternatively, any size output capacitor C_{out} is able to be used.

In operation, when the load 206 is coupled to the power converter 204, the controller 214 of the power converter 204 outputs a transistor control signal having one or more pulse cycles to the gate terminal of the transistor 212 that causes the transistor 212 to repeatedly turn on and off as the pulse cycles alternate between high and low states. As a result, power from the power source 202 is alternately drawn into the transformer T1 and discharged to the output capacitor C_{out} such that the output capacitor C_{out} is charged to an output voltage V_{out} that is supplied to the load 206. A portion of the power is discharged to the capacitor C1 and the controller 214 via the power saving element 216. This portion of the power is able to be used/recycled by the controller 214 in order to continue to output the transistor control signal.

Concurrently, the wake-up element 208 monitors the output voltage V_{out} on the output capacitor C_{out} and the load 206 connection status. If the wake-up element 208 detects that the load 206 is coupled with the power converter 204, the wake-up element 208 transmits a command signal to the energy saving element 216 that causes the energy saving element 216 to keep the input voltage V_{in} , the transformer T1 and the capacitor C1 coupled to the

controller 214 such that the controller 214 is able to operate normally. Alternatively, the energy saving element 216 is able to be omitted or able to keep the input voltage V_{in} , the transformer T1 and the capacitor C1 coupled to the controller 214 by default such that the command signal from the wake-up element 208 is able to be omitted. If the wake-up element 208 detects that the load 206 is not coupled with the power converter 204 and the output voltage V_{out} is above a threshold voltage or within a desired range, the wake-up element 208 transmits a command signal to the power saving element 216 that causes the power saving element 216 to disconnect or otherwise prevent the input voltage V_{in} , the transformer T1 and the capacitor C1 from communicating with the controller 214 such that the normal operation of the controller 214 is stopped. Alternatively, the wake-up element 208 is able to directly couple and send the command signal to the controller 214 such that although the input voltage V_{in} , the transformer T1 and the capacitor C1 remain coupled with the controller 214, they are able to be disregarded by the controller 214 based on the commands received from the wake-up element 208 and the controller 214 is prevented from wasting power. In some such embodiments, the power saving element 216 is able to be incorporated into the controller 214 or omitted. In some embodiments, the desired range is able to be based on the load 206 and the threshold voltage is able to be the minimum voltage that the load 206 is able to receive upon recoupling to the power converter 204 without resulting in an error. This prevents the controller 214 from wasting power by continually attempting to recharge the output voltage V_{out} . In particular, because the output capacitor C_{out} acts like a battery when the load 206 is decoupled, the output voltage V_{out} on the capacitor C_{out} takes up to hundreds of milliseconds to decay tenths of a volt. As a result, the recharging of the output voltage V_{out} is able to be delayed for hundreds of milliseconds without the output voltage V_{out} falling to too low a value to properly recover when the load 206 is recoupled.

If the wake-up element 208 detects that the load 206 is not coupled with the power converter 204 and the output voltage V_{out} is below the threshold voltage or outside the desired range, the wake-up element 208 transmits a command signal to the energy saving element 216 that causes the energy saving element 216 to reconnect or otherwise ensure the input voltage V_{in} , the transformer T1 and the capacitor C1 are coupled with the controller 214 such that the controller begins 214 to operate for a period of time. Specifically, the command

signal of the wake-up element 208 controls the energy saving element 216 such that the controller 214 only outputs a desired number of cycles of the switch command signal to the transistor 212 before the input voltage V_{in} , the transformer T1 and the capacitor C1 are again decoupled from the controller 214. In some embodiments, the desired number of cycles is a predetermined number such as three cycles. Alternatively, the desired number of cycles is able to be determined dynamically by the wake-up element 208 by monitoring the output voltage V_{out} as the controller 214 operates and stopping the operation of the controller 214 when the output voltage V_{out} is at a desired level or within a desired range. Alternatively, the wake-up element 208 is able to be directly coupled to the controller 214 and the wake-up element 208 is able to transmit the command signal directly to the controller 214 to cause the controller 214 to operate for the desired number of cycles while the input voltage V_{in} , the transformer T1 and the capacitor C1 remain disconnected by the energy saving element 216. In any case, this operation is able to continue in order to maintain the output voltage V_{out} at the desired level until the load 206 is recoupled to the coupling point 210. As a result, the system 200 is able to provide the advantage of only drawing minimal amount of power from the power source 202 necessary to recharge the output voltage V_{out} to the desired level. In particular, the cumulative period of the number of cycles required to recharge the output voltage V_{out} on the output capacitor C_{out} is able to be only tens of microseconds. Thus, when compared to the decay time of the output voltage V_{out} , for every tens of microseconds of operation the power converter 204 is able to be off for hundreds of milliseconds. Consequently, the system 200 provides the advantage of consuming quasi-zero power from the power source 202 when operating in no-load conditions.

Figure 3 illustrates a flow chart of a method of powering a load with a power supply when coupled to the load and for drawing a quasi-zero amount of power from the power supply when not coupled to the load according to some embodiments. At the step 302, the wake-up element 208 detects if the load 206 is coupled with the power converter 204. At the step 304, the wake-up element 208 detects the output voltage V_{out} of the power converter 204. At the step 306, the wake-up element 208 transmits a recharge signal to the power converter 204 if the load 206 is not coupled with the power converter 204 and the output voltage V_{out} is below a threshold voltage. At the step 308, the power converter 204 recharges the output

voltage V_{out} to a predefined sleep voltage upon receiving the recharge signal. In some embodiments, the power converter 204 recharges the output voltage V_{out} by operating until the wake-up element 208 detects that the output voltage V_{out} equals the predefined sleep voltage. In some embodiments, the power converter 204 recharges the output voltage V_{out} by operating for a predetermined number of the switch command signal cycles. For example, in some embodiments, the power converter 204 operates for three cycles of 5 microseconds each in order to recharge the output voltage V_{out} from 4.75 volts to 5 volts. In some embodiments, the predefined sleep voltage equals the maximum operating voltage of the load 206 and the threshold voltage equals the minimum operating voltage of the load 206. In some embodiments, the number of switching cycles that the converter 204 operates for is adjusted in order to maximize the ratio of the time that the output voltage V_{out} takes to drop to the threshold voltage versus the combined period of the predetermined number of switching cycles. As a result, the method provides the benefit of consuming quasi-zero power from the power supply 202 when the power converter 204 is not coupled with the load 206.

The method, apparatus and system of power converter quasi-zero power consumption in a no load state described herein has many advantages. Specifically, the system prevents the power converter from drawing unnecessary power from the power source when the load is not coupled to the converter and the output voltage does not require recharging, thereby reducing power consumption. Similarly, the system ensures that the minimum amount of power is drawn from the power source in order to recharge the output voltage when the load is not coupled to the converter and the output voltage falls below a minimum voltage threshold value. Accordingly, the power converter with quasi-zero no load power consumption described herein has numerous advantages.

The power converter system has been described in terms of specific embodiments incorporating details to facilitate the understanding of the principles of construction and operation of the power converter system. The specific configurations shown and the methodologies described in relation to the various modules and the interconnections therebetween are for exemplary purposes only. Such reference herein to specific embodiments and details thereof is not intended to limit the scope of the claims appended hereto. It will be apparent to those skilled in the art that modifications may be made in the

embodiments chosen for illustration without departing from the spirit and scope of the power converter system.

CLAIMS

What is claimed is:

1. A power converter system for powering a load when coupled to the load and for drawing a quasi-zero amount of power when not coupled to the load, the system comprising:
 - a. a power supply for supplying an input power;
 - b. a power converter coupled with the power supply, wherein the power converter produces an output voltage from the input power; and
 - c. a wake-up element coupled to the power converter, wherein when the load is disconnected from the power converter and the output voltage drops below a threshold voltage the wake-up element causes the power converter to recharge the output voltage to a predefined sleep voltage.
2. The system of claim 1, wherein the power converter is a switch mode power supply having a switching signal comprising one or more cycles, wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage.
3. The system of claim 2, wherein the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate until the wake-up element detects that the output voltage equals the predefined sleep voltage.
4. The system of claim 2, wherein the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate for a predetermined number of the switching signal cycles.
5. The system of claim 4, wherein the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load.

6. The system of claim 5, wherein the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles.
7. The system of claim 5, wherein the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while keeping the output voltage above the threshold voltage.
8. The system of claim 5, wherein the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage.
9. The system of claim 1, wherein the power converter and the wake-up element are a part of a single integrated circuit.
10. A power converter device for powering a load when coupled to the load and for drawing a quasi-zero amount of power when not coupled to the load, the device comprising:
 - a. a power converter configured to produce an output voltage from an input power; and
 - b. a wake-up element coupled to the power converter, wherein when the load is disconnected from the power converter and the output voltage drops below a threshold voltage the wake-up element causes the power converter to recharge the output voltage to a predefined sleep voltage.
11. The device of claim 10, wherein the power converter is a switch mode power supply having a switching signal comprising one or more cycles, wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage.
12. The device of claim 11, wherein the wake-up element causes the power converter to

recharge the output voltage to the predefined sleep voltage by causing the power converter to operate until the wake-up element detects that the output voltage equals the predefined sleep voltage.

13. The device of claim 11, wherein the wake-up element causes the power converter to recharge the output voltage to the predefined sleep voltage by causing the power converter to operate for a predetermined number of the switching signal cycles.

14. The device of claim 13, wherein the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load.

15. The device of claim 14, wherein the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles.

16. The device of claim 14, wherein the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while keeping the output voltage above the threshold voltage.

17. The device of claim 14, wherein the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage.

18. The device of claim 10, wherein the power converter and the wake-up element are a part of a single integrated circuit.

19. A method of powering a load with a power supply when coupled to the load and for drawing a quasi-zero amount of power from the power supply when not coupled to the load,

the method comprising:

- a. detecting if the load is coupled with a power converter with a wake-up element;
- b. detecting an output voltage of the power converter with the wake-up element;
- c. transmitting a recharge signal from the wake-up element to the power converter if the load is not coupled with the power converter and the output voltage is below a threshold voltage; and
- d. recharging the output voltage to a predefined sleep voltage with the power converter upon receiving the recharge signal.

20. The method of claim 19, wherein the power converter is a switch mode power supply having a switching signal comprising one or more cycles wherein the switching signal controls when input power is drawn from the power supply to produce the output voltage.

21. The method of claim 20, wherein the recharging comprises operating the power converter until the wake-up element detects that the output voltage equals the predefined sleep voltage.

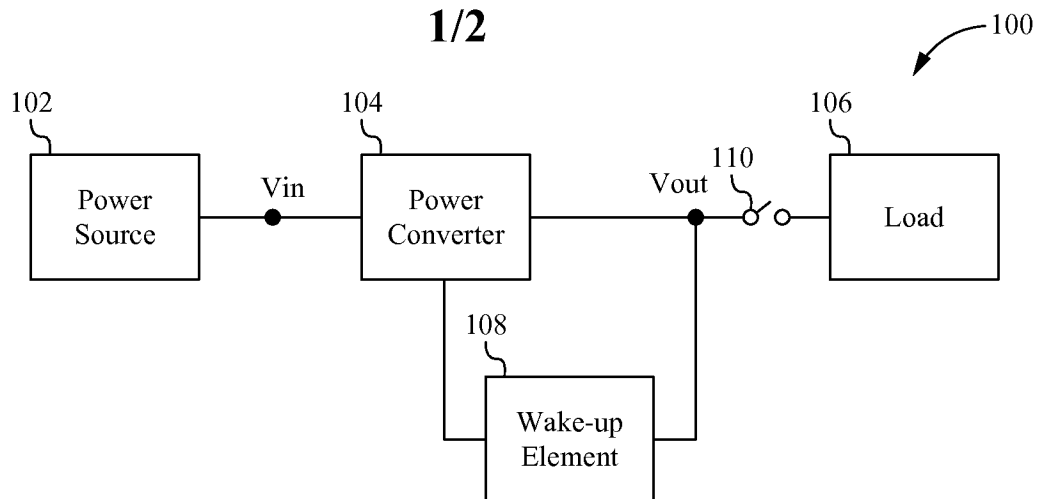
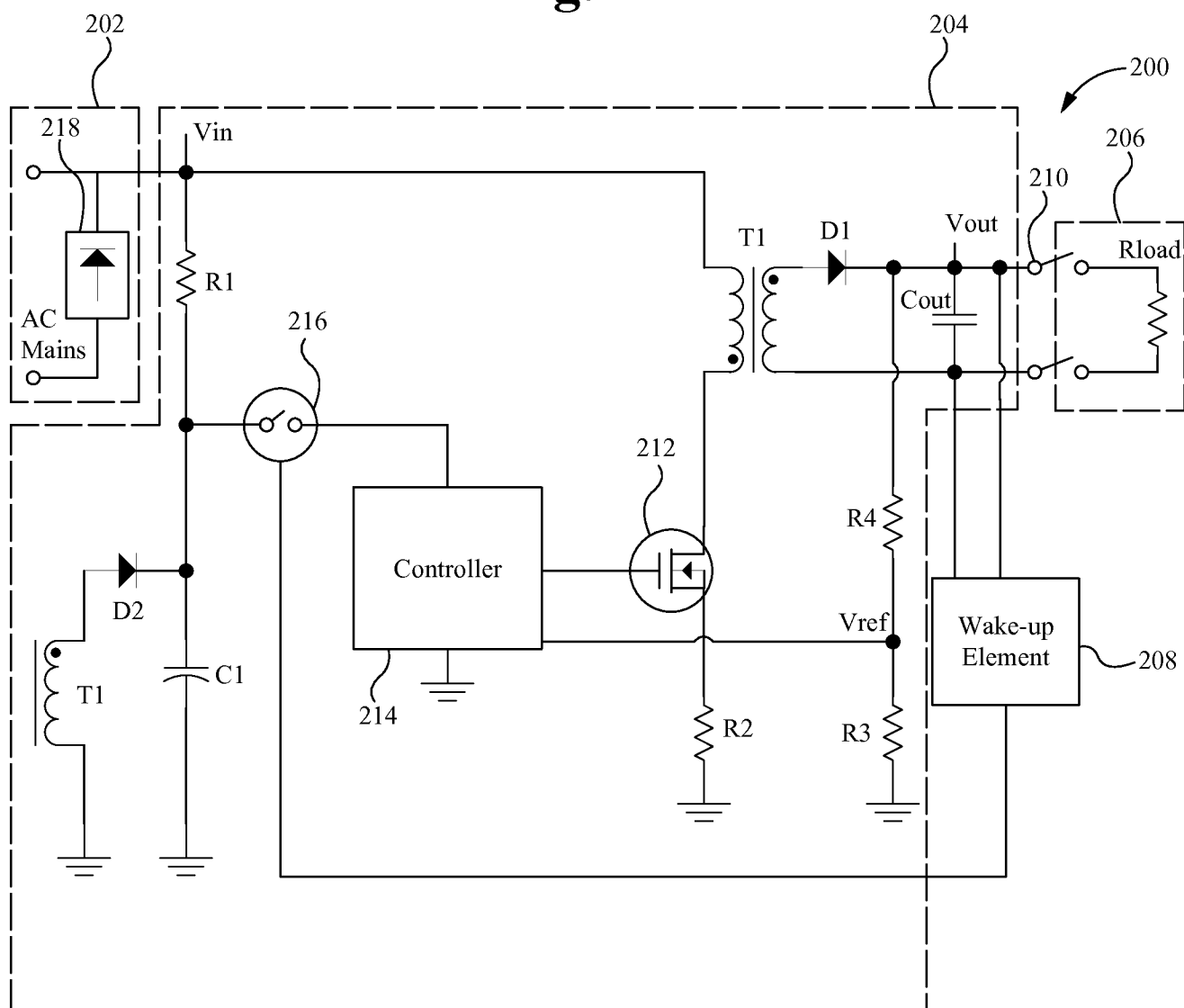
22. The method of claim 20, wherein the recharging comprises operating the power converter for a predetermined number of the switching signal cycles.

23. The method of claim 22, wherein the predefined sleep voltage equals the maximum operating voltage of the load and the threshold voltage equals the minimum operating voltage of the load.

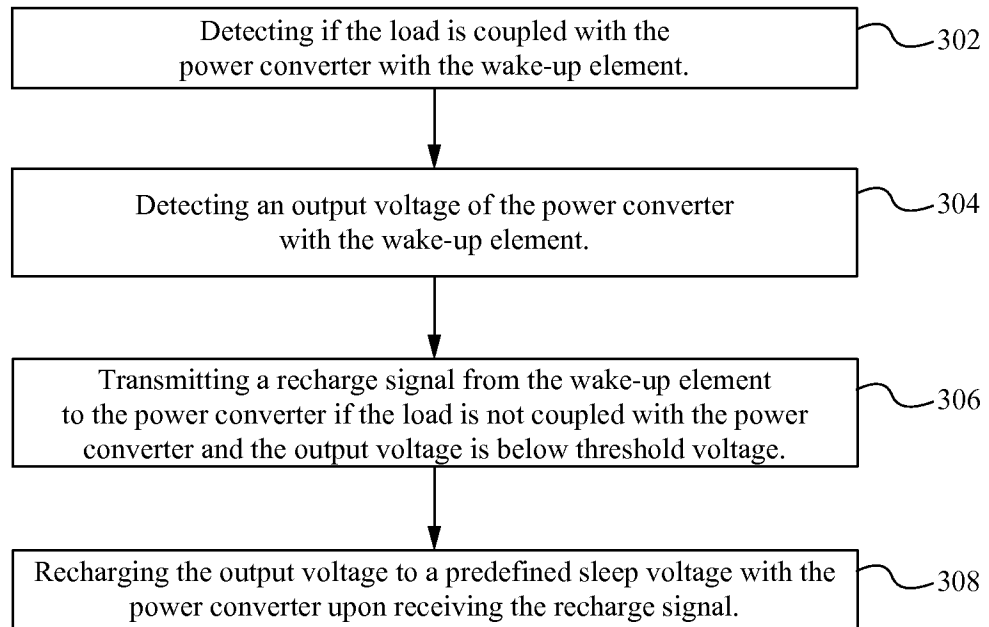
24. The method of claim 23, wherein the predetermined number of switching signal cycles equals the number of cycles required to maximize the ratio of the time that the output voltage takes to drop to the threshold voltage versus the combined period of the predetermined number of switching signal cycles.

25. The method of claim 23, wherein the predetermined number of switching signal cycles equals the number of cycles required to minimize the duty cycle of the power converter while keeping the output voltage above the threshold voltage.
26. The method of claim 23, wherein the predetermined number of switching signal cycles equals the minimum amount of cycles required to recharge the output voltage to the predefined sleep voltage.
27. The method of claim 19, wherein the power converter and the wake-up element are a part of a single integrated circuit.

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**Fig. 1****Fig. 2**

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**Fig. 3**

A. CLASSIFICATION OF SUBJECT MATTER**H02M 3/28(2006.01)i, H02M 3/24(2006.01)i, H02M 3/22(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H02M 3/28; H02M 3/335; G05F 1/40; H03M 1/12; H02M 3/155; H02J 7/00; G05F 1/56; H02M 3/24; H02M 3/22

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

eKOMPASS(KIPO internal) & Keywords:power converter, SMPS, switch, wake-up, sleep, standby, charge, efficiency, power saving**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7304464 B2 (MATTHEW WENG et al.) 04 December 2007 See column 3, lines 11-16, column 5, lines 4-22, column 6, lines 66-67, claims 1-3, 16-18 and figures 1-3.	1-27
A	US 6188587 B1 (JEONG-YUL YUN et al.) 13 February 2001 See column 3, line 46-column 6, line 29 and figures 1-5.	1-27
A	JP 2009-177909 A (DENSO CORP.) 06 August 2009 See abstract, paragraphs [0025]-[0073] and figures 1-2.	1-27
A	JP 2009-278822 A (NANAO CORP.) 26 November 2009 See abstract, paragraphs [0020]-[0044] and figures 1-3.	1-27
A	KR 10-1999-0069442 A (HYUNDAI MICRO ELECTRONICS CO., LTD.) 06 September 1999 See abstract, claim 1 and figures 1-3.	1-27



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search

27 September 2013 (27.09.2013)

Date of mailing of the international search report

01 October 2013 (01.10.2013)

Name and mailing address of the ISA/KR

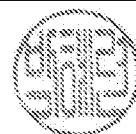
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/049793

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 7304464 B2	04/12/2007	CA 2576705 A1	15/09/2007
		CA 2576705 C	08/09/2009
		CN 100461597 C0	11/02/2009
		CN 101039070 A	19/09/2007
		EP 1835603 A2	19/09/2007
		JP 2007-252185 A	27/09/2007
		JP 4422735 B2	24/02/2010
		KR 10-0875591 B1	23/12/2008
		KR 10-2007-0093877 A	19/09/2007
		TW I328919 A	11/08/2010
		TW I328919 B	11/08/2010
		US 2007-0216372 A1	20/09/2007
US 6188587 B1	13/02/2001	KR 10-0263031 B1	01/08/2000
JP 2009-177909 A	06/08/2009	EP 2083497 A2	29/07/2009
		EP 2083497 A3	05/10/2011
		JP 4479797 B2	09/06/2010
		US 2009-0184700 A1	23/07/2009
		US 8154262 B2	10/04/2012
JP 2009-278822 A	26/11/2009	JP 4523655 B2	11/08/2010
KR 10-1999-0069442 A	06/09/1999	None	