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(54) **POWER MANAGEMENT METHOD CAPABLE OF PREVENTING AN OVER CURRENT EVENT BY PERFORMING A POWER CONTROL OPERATION**

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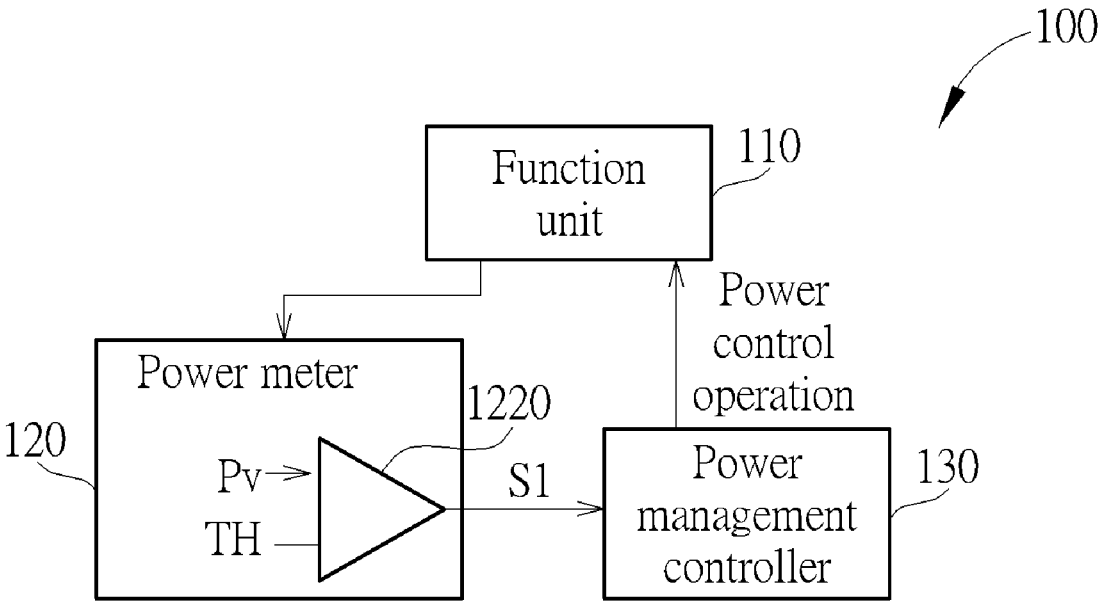
(52) **U.S. Cl.**
CPC ***H02M 1/32*** (2013.01)

(57) **ABSTRACT**

A power management method includes generating a power related value; notifying a power management controller if the power related value has passed a threshold; and performing a power control operation by the power management controller. The power control operation prevents an over current event.



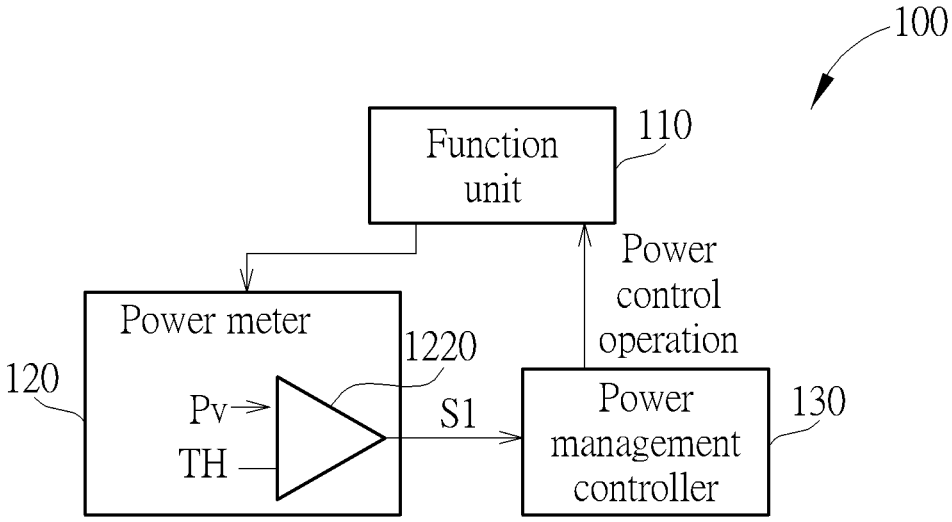

100
Function unit
110
Power control operation
Power meter
1220
120
Pv
TH
S1
Power management controller
130

FIG. 1

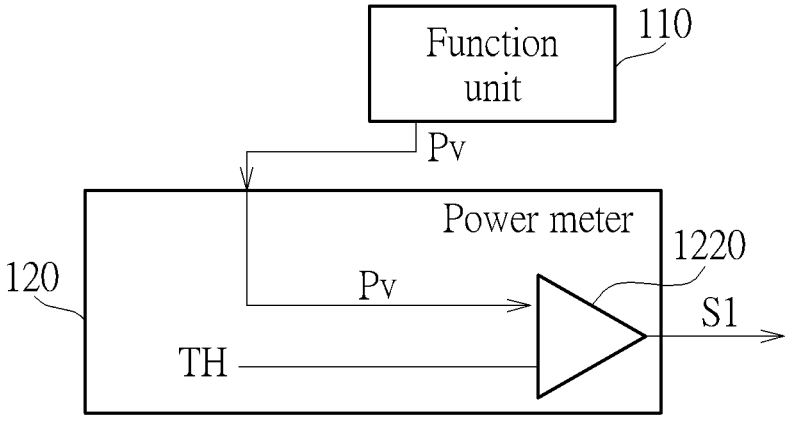

Function unit
110
Pv
Power meter
1220
120
Pv
S1
TH

FIG. 2

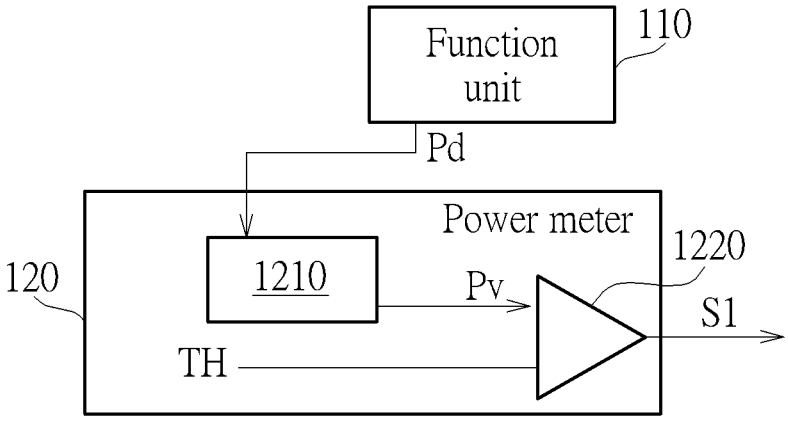

Function unit
110
Pd
Power meter
1220
120
1210
Pv
S1
TH

FIG. 3

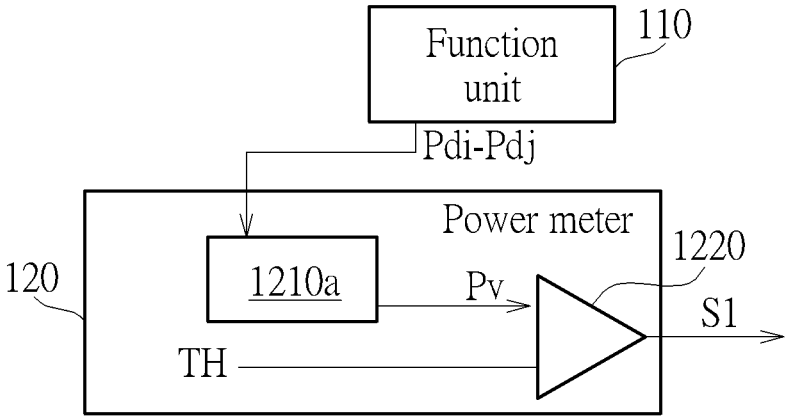

Function unit
110
Pdi-Pdj
Power meter
1220
120
1210a
Pv
S1
TH

FIG. 4

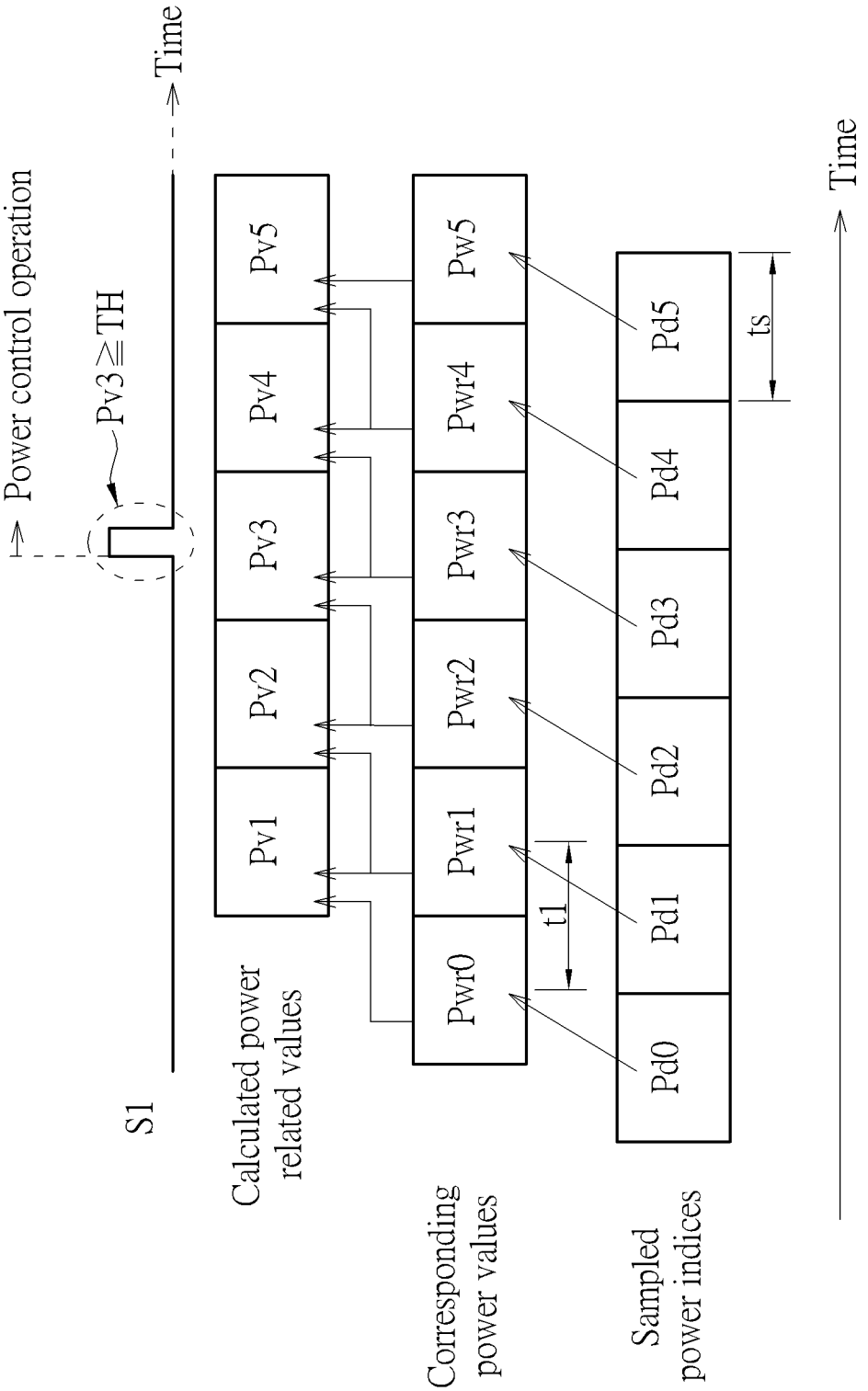

Power control operation
Time
Pv3≧TH
S1
Calculated power related values
Pv1
Pv2
Pv3
Pv4
Pv5
Corresponding power values
Pwr0
Pwr1
Pwr2
Pwr3
Pwr4
Pw5
t1
Sampled power indices
Pd0
Pd1
Pd2
Pd3
Pd4
Pd5
ts
Time

FIG. 5

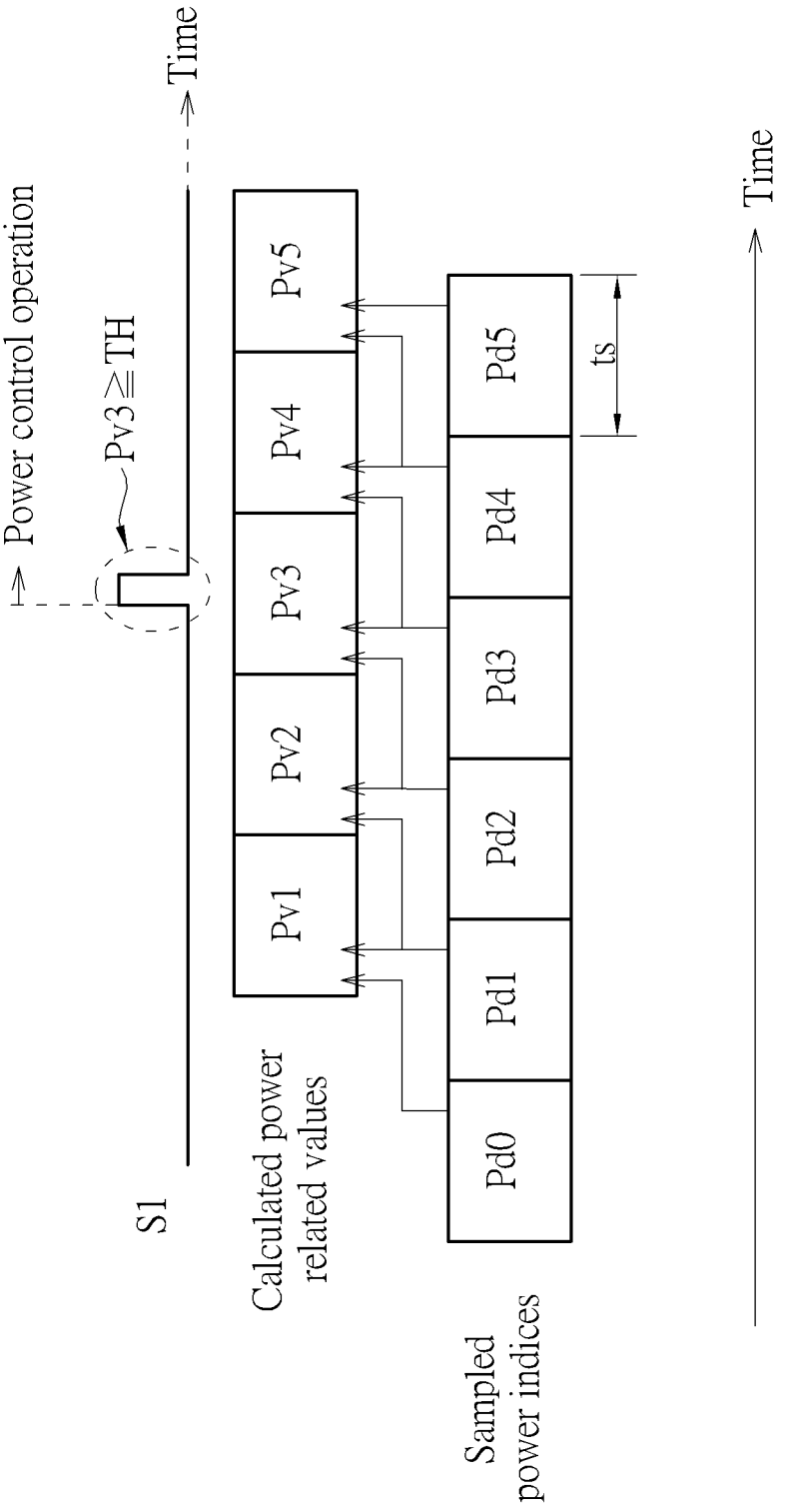

Power control operation
Time
Pv3 ≧ TH
S1
Calculated power related values
Pv1
Pv2
Pv3
Pv4
Pv5
Sampled power indices
Pd0
Pd1
Pd2
Pd3
Pd4
Pd5
ts
Time

FIG. 6

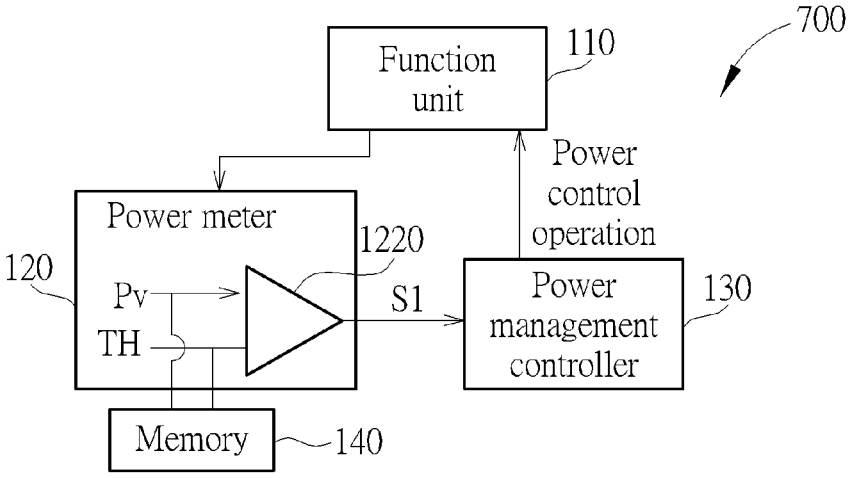

700
Function unit
110
Power control operation
Power meter
1220
120
Pv
TH
S1
Power management controller
130
Memory
140

FIG. 7

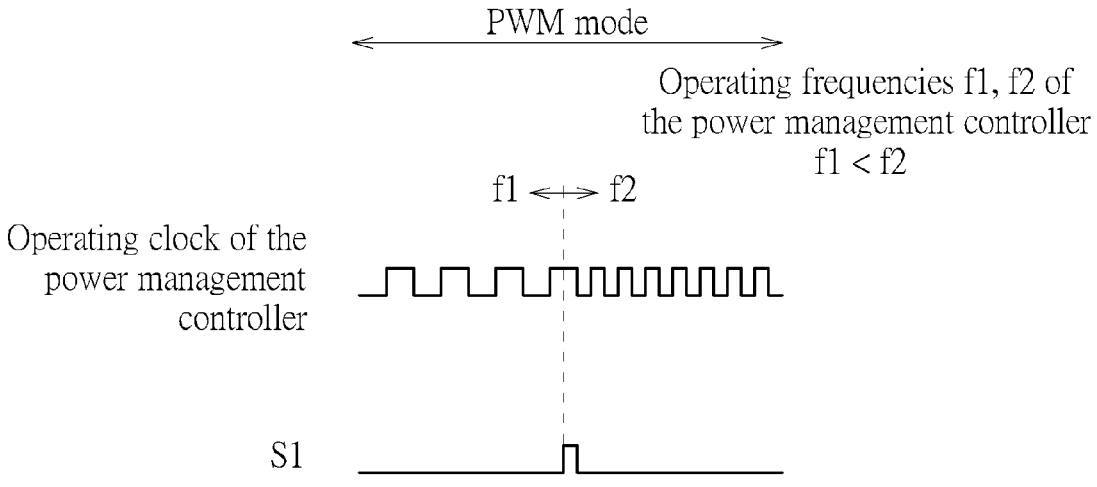

PWM mode
Operating frequencies f1, f2 of the power management controller
f1 < f2
f1
f2
Operating clock of the power management controller
S1

FIG. 8

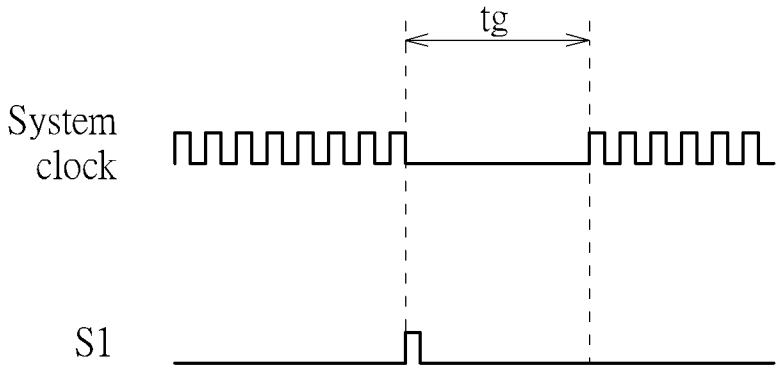

tg
System clock
S1

FIG. 9

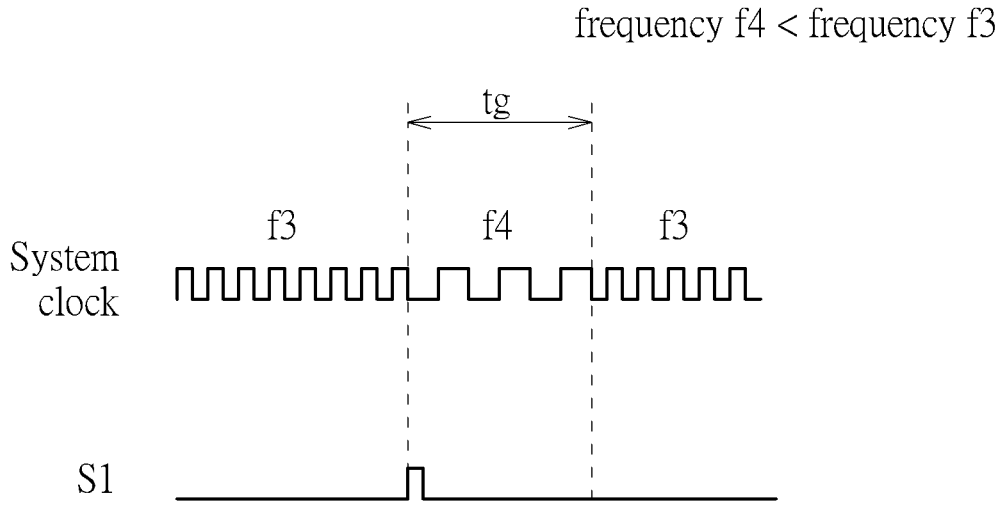

frequency f4 < frequency f3
tg
f3
f4
f3
System clock
S1

FIG. 10

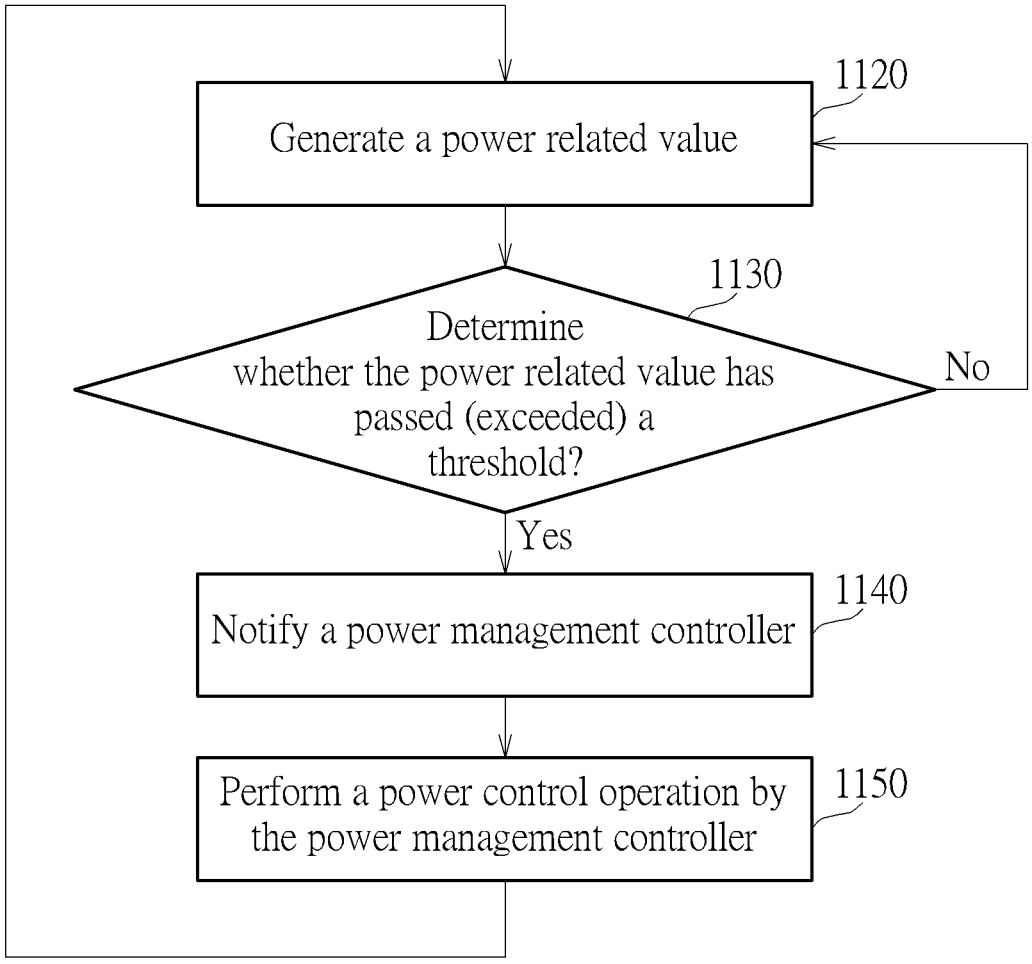

1120
Generate a power related value
1130
Determine whether the power related value has passed (exceeded) a threshold?
No
Yes
1140
Notify a power management controller
1150
Perform a power control operation by the power management controller

FIG. 11

POWER MANAGEMENT METHOD CAPABLE OF PREVENTING AN OVER CURRENT EVENT BY PERFORMING A POWER CONTROL OPERATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional application No. 62/201,054 filed Aug. 04, 2015. The above-mentioned application is included in its entirety herein by reference.

BACKGROUND

[0002] With the evolution of advanced integrated chip (IC) fabrication technology, number of components and complexity of circuitry disposed on a chip are increasing, and the System-on-Chip (SoC) solution is therefore feasible. Also the operating voltages supplied to SoC chips are decreased to lower levels gradually, in order to achieve a more competitive product specification. When the required power consumption remains substantially unchanged, the reduction of operating voltage has made it difficult to guarantee the stability of output voltages of SoC chips, especially when drawing a large operating current. The instability of output voltages caused by a large operating current drawn by the chip is an over current event. A systematic solution for preventing the over current event is required in the field.

SUMMARY

[0003] An implementation of the present disclosure discloses a power management method. The power management method includes generating a power related value; notifying a power management controller if the power related value has passed a threshold; and performing a power control operation by the power management controller. The power control operation prevents an over current event.

[0004] Another implementation of the present disclosure discloses a power management system. The power management system includes a function unit, a power meter and a power management controller. The power meter is coupled to the function unit for generating a power related value corresponding to the function unit. The power management controller is coupled to the power meter for performing a power control operation for preventing an over current event when being notified by the power meter. The power meter notifies the power management controller when the power related value has passed a threshold.

[0005] These and other objectives of the present disclosure will no doubt become obvious to those of ordinary skill in the art after reading the following detailed description of the preferred implementation that is illustrated in the various figures and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** illustrates a power management system according to an implementation of the present disclosure.

[0007] FIG. **2** illustrates a schematic diagram of the power meter and the function unit according to an implementation of the present disclosure.

[0008] FIG. **3** illustrates a schematic diagram of the power meter and the function unit according to another implementation of the present disclosure.

[0009] FIG. **4** illustrates a schematic diagram of the power meter and the function unit according to yet another implementation of the present disclosure.

[0010] FIG. **5** illustrates the generation of the foresaid slew rate according to FIG. **4** and an implementation of the present disclosure.

[0011] FIG. **6** illustrates another dynamic diagram for describing the generation of the foresaid slew rate according to FIG. **4** and another implementation of the present disclosure.

[0012] FIG. **7** illustrates a power management system according to another implementation of the present disclosure.

[0013] FIG. **8** illustrates a waveform diagram corresponding to the power control operation according to an implementation of the present disclosure.

[0014] FIG. **9** illustrates a waveform diagram corresponding to a power control operation according to another implementation of the present disclosure.

[0015] FIG. **10** illustrates a waveform diagram corresponding to a power control operation according to yet another implementation of the present disclosure.

[0016] FIG. **11** illustrates a flow chart of a power management method according to an implementation of the present disclosure.

DETAILED DESCRIPTION

[0017] FIG. **1** illustrates a power management system **100** according to an implementation of the present disclosure. The power management system **100** may include a function unit **110**, a power meter **120** and a power management controller **130**. The power meter **120** may be coupled to the function unit **110** for generating a power related value Pv corresponding to the operation of the function unit **110**. The power management controller **130** may be coupled to the power meter **120** for performing a power control operation for preventing an over current event when being notified by the power meter **120**. According to an implementation of the present disclosure, the power meter **120** may notify the power management controller **130** by sending a notification signal S**1**. The power meter **120** may notify the power management controller **130** when the power related value Pv has exceeded a threshold TH. The power meter **120** may include a comparator unit **1220** configured to check whether the power related value Pv has passed the threshold TH, and generating the foresaid notification signal S**1**.

[0018] FIG. **2** illustrates a schematic diagram of the power meter **120** and the function unit **110** according to an implementation of the present disclosure. In FIG. **2**, the power meter **120** gets the power related value Pv by sampling the function unit **110**. That is to say, the power related value Pv may be sampled and obtained from the function unit **110**. The power related value Pv shown in FIG. **2** may include a current level and/or a voltage level corresponding to the operating current drawn by the function unit **110**. The power related value Pv may be sampled by an electrical digital power meter or a detector designed for sampling a current value and/or a voltage value.

[0019] FIG. **3** illustrates a schematic diagram of the power meter **120** and the function unit **110** according to another implementation of the present disclosure. In FIG. **3**, a power

index Pd may be sampled and collected to a power related value generator **1210** to be post-processed for generating the power related value Pv. For example, when the sampled power index Pd is a detected voltage value, the power related value generator **1210** may perform an analog-to-digital operation, a power consumption calculation operation and a level determination operation to determine a corresponding power related value Pv. A set of lookup tables may be used in the process. The power related value Pv may then be compared with the threshold TH. In FIGS. **2-3**, the power related value Pv may be an index proportional to the power consumption such as (but not limited to) a current level, a voltage level, a data rate, an active duty parameter according to implementations of the present disclosure.

[0020] FIG. **4** illustrates a schematic diagram of the power meter **120** and the function unit **110** according to yet another implementation of the present disclosure. In FIG. **4**, the power meter **120** is used for generating the power related value Pv by sampling a plurality of power indices Pdi-Pdj from the function unit **110** for generating a slew rate from the plurality of power indices Pdi-Pdj. In FIG. **4**, the power indices Pdi-Pdj may be indices proportional to the power consumption such as current levels, voltage levels, data rates, active duty parameters according to implementations of the present disclosure. The power related value Pv may be the generated slew rate. In FIG. **4**, a power related value generator **1210***a* generates slew rate from the sampled power indices Pdi-Pdj The power indices Pdi-Pdj may include a plurality of current levels and/or a plurality of voltage levels corresponding to the operating current drawn by the function unit **110**. The power indices Pdi-Pdj may be sampled by an electrical digital power meter or a detector designed for sampling current values and/or voltage values. The slew rate mentioned here may be a rate of change per time unit. For example, if a first power index is sampled as 5.2 volt, a second power index is sampled as 5.8 volt, and the time interval between two samplings is 500 msec, then the slew rate is 1.2 volt/sec.

[0021] In this example, the obtained slew rate 1.2 volt/sec may be used as the power related value Pv to be compared with the threshold TH, or be post-processed for generating the power related value Pv.

[0022] As mentioned above, the power meter **120** shown in FIGS. **1-4** may be or include a current detector, a voltage detector, a bandwidth detector, an active duty detector or a power index detector for sampling at least a power index or power related value (e.g. a current level or a voltage level) corresponding to the power consuming status of the function unit **110**.

[0023] FIG. **5** illustrates the generation of the foresaid slew rate according to FIG. **4** and an implementation of the present disclosure. Taking the power indices Pd**0**-Pd**5** for example (where the Pd**0**-Pd**5** may be a set of the Pdi-Pdj), the power indices Pd**0**-Pd**5** may be sampled sequentially by the power meter **120**. Since each of a power value Pwr**1**-Pwr**5** may be proportional to each of the power indices Pd**0**-Pd**5**, the power values Pwr**1**-Pwr**5** may be calculated by utilizing the power indices Pd**0**-Pd**5**. Each of the power related values Pv**1**-Pv**5** may correspond to the power related value Pv shown in FIGS. **1-4**. The power related values Pv**1**-Pv**5** may then be obtained by performing slew rate calculation. For example, the power related values Pv**1** may correspond to the slew rate of the power values Pwr**1** and Pwr**2**. Each power index Pd may be a parameter corresponding to a power related event such as a sampled data rate or an observed bandwidth in use. Each power index Pd may be positively correlated with actual power consumption. A corresponding power value Pwr corresponding to a power index Pd may be derived according to the power index Pd and experience. Each power related value Pv may be related to the variation of the power values Pwr. For example, when a parameter t**1** (shown in FIG. **5**) may be a predetermined time interval, the power related value Pv**1** may be positively correlated with the variation of Pwr**0** and Pw**1**. Similarly, the power related value Pv**2** may be calculated using the power values Pwr**1** and Pwr**2**, the power related value Pv**3** may be calculated using the power values Pwr**2** and Pwr**3**, and so on. The power related value Pv is not limited to be generated by slew rate calculation described above, a lookup table may be used to obtained the power related value Pv in other implementations of the present disclosure. In the example shown in FIG. **5**, the power related values Pv**1** and Pv**2** fail to pass the threshold TH so that the notification signal S**1** is unnecessary to be set active. However, the power related value Pv**3** has passed the threshold TH (e.g. the power related value Pv**3** ≥ the threshold TH) so that the risk of occurring an over current event is increased, the notification signal S**1** is set active for notifying the power management controller **130** to perform a power control operation. In FIG. **5**, the active state of the notification signal S**1** is represented as a high state pulse as an example. The operation performed in FIG. **5** may be performed by the power related value generator **1210***a* in FIG. **4**. The power indices may be sampled periodically in a predetermined frequency according to an implementation of the present disclosure. For example, the power indices Pd**0**-Pv**5** may be voltage levels obtained by sampling from the function unit **100** every 50 msec. A time interval ts in FIG. **5** is to describe the sample time interval. The predetermined frequency may be programmable. When the frequency is programmed to be higher, the sensitivity may be increased.

[0024] In FIG. **5**, each power related value (e.g. any of the power related values Pv**1**-Pv**5**) corresponds to a slew rate calculated by using two power values (e.g. the power values Pwr**1**-Pwr**2**). However, as shown in FIG. **6**, a power related value may be obtained by calculating the slew rate of two sampled power indices directly without calculating the power value first according to another implementation of the present disclosure. FIG. **6** illustrates another dynamic diagram for describing the generation of the foresaid slew rate according to FIG. **4** and another implementation of the present disclosure. In FIG. **6**, the power related value Pv**1** may be a slew rate calculated from the sampled power indices Pd**0** and Pd**1**, the power related value Pv**2** may be a slew rate calculated from the sampled power indices Pd**1** and Pd**2**, and so on. Since the operating principle is similar to the example of FIG. **5**, it is not described repeatedly. The operation performed in FIG. **6** maybe performed by the power related value generator **1210***a* in FIG. **4**.

[0025] FIG. **7** illustrates a power management system **700** according to another implementation of the present disclosure. The power management system **700** may be similar to the power management system **100** shown in FIG. **1** but further include a memory **140**. The memory **140** may be coupled to the power meter **120** and used to store the threshold TH and the power related value Pv. The power related value Pv and the used threshold TH may be stored in the memory **140** for statistic or debugging analysis. In

another example, a set of values may be stored in the memory **140** and one of the stored values may be selected to be the threshold TH.

[0026] The function unit **110** may include electrical units made of digital circuitry, analog circuitry and/or memory units for executing specific functions. In particular, the function unit **110** may be a functional block consuming larger power and in need of drawing a large operating current in some scenarios. According to implementations of the present disclosure, the function units **110** may be a (but not limited to) a central processing unit (CPU), graphics processing unit (GPU) or BUS unit of an SoC. For example, when the function unit **110** is a GPU, and a set of complex images are processed by the function unit **110**, a large operating current may be drawn by the function unit **110** in a short time so that the power related value Pv may pass the threshold TH, and the power management controller **130** may perform a power control operation for preventing an over current event and stabilizing the output voltage. According to an implementation of the present disclosure, the power management controller **130** may be implemented as an IC such as a power management IC (PMIC), or a specific functional hardware module in a chip. According to another implementation of the present disclosure, the power management controller **130** may include a control module and a power supply module for both controlling and providing power to the function unit **110**.

[0027] The above mentioned power control operation may include the following operations:

[0028] (i) the power management controller **130** outputting a higher power output to the function unit **110** by entering a second mode from a first mode;

[0029] (ii) the power management controller **130** adjusting an operating frequency in a pulse width modulation (PWM) mode; or

[0030] (iii) the power management controller **130** throttling a system clock for a predetermined time interval for reducing a current drawn.

[0031] In the operation (i), the first mode may be a pulse frequency modulation (PFM) mode and the second mode may be a pulse width modulation (PWM) mode according to an implementation of the present disclosure. Since the power management controller **130** may support a higher power output and better driving ability in the PWM mode than in the PFM mode, entering the PWM mode from the PFM mode may prevent an over current event and related IR-drop (i.e. avoltage drop produced by a current (I) passing through a resistance with a resistance value (R)). Regarding the operation (ii), FIG. **8** may be referred as an example. FIG. **8** illustrates a waveform diagram corresponding to the power control operation according to an implementation of the present disclosure. In FIG. **8**, the waveform of an operating clock of the power management controller is shown. As shown in FIG. **8**, when the notification signal S**1** is set active, the power management controller **130** may adjust the operating frequency of the power management controller **130** to be a frequency f**2** from a frequency f**1**, where the frequency f**2** maybe higher than a frequency f**1**. By applying a higher operating frequency, the power management controller **130** may increase the power supplying ability for the function unit **110** to process a heavy duty with lower risk of occurring an over current event. Regarding the operation (iii), FIGS. **9** and **10** may be referred as examples. FIG. **9** illustrates a waveform diagram corresponding to a power control operation according to another implementation of the present disclosure. In FIG. **9**, when the notification signal S**1** is set active, the power management controller **130** may throttle to stop the system clock for a predetermined time interval tg, and the operating current drawn by the function unit **110** may be reduced in the time interval tg. FIG. **10** illustrates a waveform diagram corresponding to a power control operation according to yet another implementation of the present disclosure. In FIG. **10**, when the notification signal S**1** is set active, the power management controller **130** may throttle the system clock for a predetermined time interval tg so that the frequency of the system clock is changed to a frequency f**4** from a frequency f**3** in the predetermined time interval tg. The frequency f**4** maybe lower than the frequency f**3** for reducing the drawn current. For example, frequency f**3** maybe a multiple of the frequency f**4** so that the frequency f**3** may be m times frequency f**4**, where m is a positive number and not limited to be an integer.

[0032] In FIGS. **5-10**, the active state of the notification signal S**1** is represented as a high state pulse as an example. However, according to other implementations, the active state of the notification signal S**1** maybe a constant high state or a constant low state, and the foresaid power control operation may be performed only during the interval in which the notification signal S**1** is set active. In all cases, reasonable state transition time and response time may be required.

[0033] FIG. **11** illustrates a flow chart of a power management method **1100** according to an implementation of the present disclosure. FIG. **11** maybe referred with referring to FIGS. **1** and **7**. The power management method **1100** may include the following steps:

[0034] Step **1120**: generate a power related value Pv;

[0035] Step **1130**: determine whether the power related value Pv has passed (exceeded) a threshold TH? If so, enter step **1140**; else enter step **1120**;

[0036] Step **1140**: notify a power management controller **130**;

[0037] Step **1150**: perform a power control operation by the power management controller **130**, go to step **1120**.

[0038] As described above, the power related value Pv may be a power index sampled from the function unit **110** or a slew rate obtained by using at least two power indices sampled from the function unit **110**, and the power control operation may be practiced with one of the foresaid operations (i)-(iii). Hence, it is not described repeatedly.

[0039] In summary, by using the power management method and the power management system disclosed according to implementations of the present disclosure, the power related value Pv may be generated and compared with the threshold TH for detecting scenarios corresponding to a high drawn current and a high risk of an over current event, and the power control operation may be performed so that the over current event and an unwanted IR drop caused by the over current event may be effectively prevented. The effect of stabilizing the functional performance and output voltage of an SoC system is significant.

[0040] Those skilled in the art will readily observe that numerous modifications and alterations of the device and method may be made while retaining the teachings of the disclosure. Accordingly, the above disclosure should be construed as limited only by the metes and bounds of the appended claims.

What is claimed is:

1. A power management method comprising:

generating a power related value;

notifying a power management controller if the power related value has passed a threshold; and

performing a power control operation by the power management controller,

wherein the power control operation prevents an over current event.

2. The power management method of claim **1** wherein generating the power related value is sampling the power related value from a function unit.

3. The power management method of claim **2**, wherein the power related value is sampled by an electrical digital power meter.

4. The power management method of claim **1** wherein generating the power related value comprises:

sampling a plurality of power indices from a function unit; and

generating a slew rate from the plurality of power indices;

wherein the power related value is the slew rate.

5. The power management method of claim **4**, wherein the plurality of power indices are sampled by an electrical digital power meter.

6. The power management method of claim **4**, wherein the plurality of power indices are sampled periodically in a programmable frequency.

7. The power management method of claim **1**, wherein the power management controller performing the power control operation comprising:

the power management controller outputting a higher power output to the function unit by entering a second mode from a first mode.

8. The power management method of claim **7**, wherein the first mode is a pulse frequency modulation (PFM) mode and the second mode is a pulse width modulation (PWM) mode.

9. The power management method of claim **1**, wherein the power management controller performing the power control operation comprising:

the power management controller adjusting an operating frequency in a pulse width modulation (PWM) mode.

10. The power management method of claim **1**, wherein the power management controller performing the power control operation comprising:

the power management controller throttling a system clock for a predetermined time interval for reducing a current draw.

11. A power management system comprising:

a function unit;

a power meter coupled to the function unit and configured to generate a power related value corresponding to the function unit; and

a power management controller coupled to the power meter and configured to perform a power control operation for preventing an over current event when being notified by the power meter;

wherein the power meter notifies the power management controller when the power related value has passed a threshold.

12. The power management system of claim **11**, wherein the power meter is configured to generate the power related value by sampling the power related value from the function unit.

13. The power management system of claim **11**, wherein the power meter is configured to generate the power related value by sampling a plurality of power indices from the function unit; and generating a slew rate from the plurality of power indices; wherein the power related value is the slew rate.

14. The power management system of claim **11**, further comprising a memory coupled to the power meter and configured to store the threshold and the power related value.

15. The power management system of claim **11**, wherein the power management controller is an integrated circuit.

16. The power management system of claim **11**, wherein the power meter is a current detector, a voltage detector, a bandwidth detector, an active duty detector or a power index detector.

* * * * *