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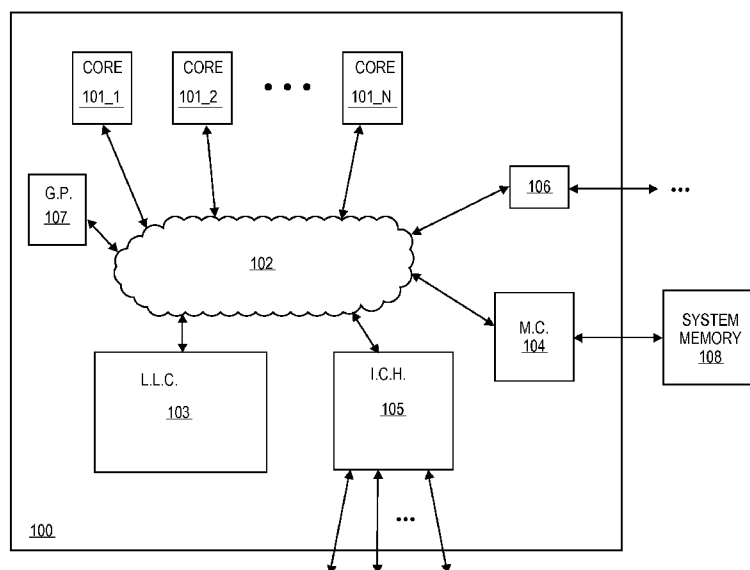
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(54) **Title:** METHOD AND APPARATUS FOR EFFICIENT STORE/RESTORE OF STATE INFORMATION DURING A POWER STATE TRANSITION



**FIG. 1**

(57) **Abstract:** A processor is described having streamlining circuitry that has a first interface to receive information from a memory describing: i) respective addresses for internal state information of a power domain; ii) respective addresses of a memory where the internal state information is stored when the power domain is powered down; and, iii) meta data for transferring the state information between the power domain and where the internal state information is stored when the power domain is powered down.

## METHOD AND APPARATUS FOR EFFICIENT STORE/RESTORE OF STATE INFORMATION DURING A POWER STATE TRANSITION

### FIELD OF INVENTION

The field of invention relates generally to computing systems, and, more specifically, to a method and apparatus for efficient store/restore of state information during a power state transition.

### BACKGROUND

Fig. 1 shows the architecture of a standard multi-core processor design 100. As observed in Fig. 1, the processor includes: 1) multiple processing cores 101\_1 to 101\_N; 2) an interconnection network 102; 3) a last level caching system 103; 4) a memory controller 104 and an I/O hub 105. Each of the processing cores contain one or more instruction execution pipelines for executing program code instructions. The interconnect network 102 serves to interconnect each of the cores 101\_1 to 101\_N to each other as well as the other components 103, 104, 105.

The last level caching system 103 serves as a last layer of cache in the processor 100 before instructions and/or data are evicted to system memory 106. The memory controller 104 reads/writes data and instructions from/to system memory 108. The I/O hub 105 manages communication between the processor and “I/O” devices (e.g., non volatile storage devices and/or network interfaces). Port 106 stems from the interconnection network 102 to link multiple processors so that systems having more than N cores can be realized. Graphics processor 107 performs graphics computations. Other functional blocks of significance (phase locked loop (PLL) circuitry, power management circuitry, etc.) are not depicted in Fig. 1 for convenience.

As the power consumption of computing systems has become a matter of concern, most present day systems include sophisticated power management functions. A common framework is to define both “performance” states and “power” states. A processor’s performance is its ability to do work over a set time period. The higher a processor’s performance state the more work it can do over the set time period. A processor’s performance can be adjusted during runtime by changing its internal clock speeds and voltage levels. A processor’s power consumption increases as its performance increases.

A processor’s different performance states correspond to different clock settings and internal voltage settings so as to effect a different performance vs. power consumption tradeoff. According to the Advanced Configuration and Power Interface (ACPI) standard the different

performance states are labeled with different “P numbers”: P0, P1, P2 . . . P\_R, where, P0 represents the highest performance and power consumption state and P\_R represents the lowest level of power consumption that a processor is able to perform work at. The term “R” in “P\_R” represents the fact that different processors may be configured to have different numbers of performance states.

In contrast to performance states, power states are largely directed to defining different “sleep modes” of a processor. According to the ACPI standard, the C0 state is the only power state at which the processor can do work. As such, for the processor to enter any of the performance states (P0 through P\_R), the processor must be in the C0 power state. When no work is to be done and the processor is to be put to sleep, the processor can be put into any of a number of different power states C1, C2 . . . CM where each power state represents a different level of sleep and, correspondingly, a different amount of time needed to transition back to the operable C0 power state. Here, a different level of sleep means different power savings while the processor is sleeping.

A deeper level of sleep therefore corresponds to slower internal clock frequencies and/or lower internal supply voltages and/or more blocks of logic that receive a slower clock frequency and/or a lower supply voltage. Increasing C number corresponds to a deeper level of sleep. Therefore, for instance, a processor in the C2 power state might have lower internal supply voltages and more blocks of logic that are turned off than a processor in the C1 state. Because deeper power states corresponds to greater frequency and/or voltage swings and/or greater numbers of logic blocks that need to be turned on to return to the C0 state, deeper power states also take longer amounts of time to return to the C0 state.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustrated by way of example and not limitation in the figures of the accompanying drawings, in which like references indicate similar elements and in which:

Fig. 1 shows a processor;

Fig. 2 shows a power state hierarchy and corresponding power domains;

Fig. 3 shows tabular information describing the power state hierarchy and corresponding power domains;

Fig. 4a shows an embodiment of a processor having streamlining circuitry for saving a power domain's internal state;

Fig. 4b shows a streamlining process for saving a power domain's internal state information;

Fig. 5 shows a streamlining process for restoring a power domain's internal state

information.

## DETAILED DESCRIPTION

Fig. 2 shows an exemplary power state hierarchy 250 that is consistent with the processor model of Fig. 1. The hierarchy 250 is exemplary to more easily illustrate the basic concepts of the present discussion. The hierarchy 250 reflects the number of functional blocks that, while the processor is in a sleep state, receive insufficient supply voltage to maintain information state. Here, as is understood by those of ordinary skill, logic circuits contain storage circuits, such as registers and memory circuits, that hold information during normal operation. If such circuits have their voltage lowered below a critical level during a processor sleep state, the information they hold will be lost if it is not saved beforehand.

The top of the hierarchy 250 reflects a power state C\_M having a maximum number of functional blocks that receive insufficient supply voltage during any particular sleep state, while, the bottom of the hierarchy 250 reflects a power state C\_M-X-Z having the smallest number of functional blocks that receive insufficient supply voltage to maintain information state. The top node C\_M of the hierarchy 250 therefore perhaps corresponds to the deepest sleep state of the processor while the bottom node C\_M-X-Z of the hierarchy 250 corresponds to a lighter sleep state of the processor. As different sleep states of the processor might also specify different clock frequencies and/or lowered supply voltages that do not fall beneath the critical supply voltage, it is possible that not all sleep states of the processor are reflected in the hierarchy. Also, for the sake of simplicity, the hierarchy 250 probably reflects less circuit blocks and/or less combinations of circuit blocks that receive insufficient supply voltage than the power states an actual processor might include. As such, it should be understood that the hierarchy 250 of Fig. 2 is illustrative for the purpose of explanation.

Each node in the hierarchy 250 is depicted to indicate which blocks of the processor receive insufficient supply voltage as part of its associated power state. That is, each node indicates, for its corresponding power state, which blocks of the processor are to have their information state saved before the power state is entered. For example, the C\_M state corresponds to all blocks of the processor receiving insufficient supply voltage, therefore, the C\_X node points to all the blocks of the processor. By contrast, the C\_M-X-Y1 state corresponds to only one general purpose core 201\_1 receiving insufficient supply voltage, therefore, the C\_M-X-Y1 node points to that specific processor core 201\_1. Further still, the C\_M-X-Z state corresponds to only one pipeline 220 within the same core 201\_1 receiving insufficient supply voltage, therefore the C\_M-X-Z node points only to one pipeline 220 within the core (the exemplary processor cores are understood to be dual pipeline cores where each

pipeline has its own dedicated power plane). Again, the hierarchy 250 and associated power state definitions are only exemplary in terms of breadth and granularity. Designers may define other sleep states without departing from the main concepts presently being discussed.

Each node of hierarchy 250 of Fig. 2 essentially outlines which block(s) of a processor should have its internal state saved prior to entry into a particular power state. For example, Fig. 2 indicates that: 1) approximately all internal state of the processor 200 should be saved prior to entry into the C\_M state; 2) all internal state of processing core 201\_1 should have its internal state saved prior to entry into the C\_M-X-Y1 state; and, 3) all internal state of pipeline 220 should have its internal state saved prior to entry into the C\_M-X-Z state. Internal state is saved prior to entry into a power state by reading the information from the registers and/or memory cells of the affected block and saving the information to another storage resource such as a memory circuit external to the processor.

A “power domain” refers to a block of circuitry whose supply voltage can be individually lowered so as to necessitate the saving of that block’s internal state information prior to entry of a power state whose definition includes lowering the block’s supply voltage beneath a critical level. As such, Fig. 2 also outlines exemplary power domains of a processor. For convenience, in most cases power domains are depicted in Fig. 2 as being commensurate with a logic block. Here, e.g., each of encircled regions 200, 210, 201\_1 and 220 of Fig. 2 correspond to a unique power domain definition. Note that larger power domains (e.g., power domain 200) can be composed of smaller power domains (e.g., power domains 203, 204, 205, 207 and 210), and, similarly, a single power domain can be implicated by more than one power state. For example, the power domain for the C\_M-X-Y1 state includes the power domain for the C\_M-X-Z power state.

Fig. 3 shows a re-representation of the hierarchy of Fig. 2 that is suitable, for instance, as recorded tabulated information within a computing system (such as within a Read Only Memory (ROM)). Fig. 3 shows, in portion 301, for each power state supported by the processor, which power domains are to receive supply voltage beneath a critical threshold so as to necessitate saving of the domain’s internal state information prior to entry into the power state.

Additionally, the tabular information of Fig. 3 also specifies, in portion 302, for each power domain: 1) the addresses of the power domain’s internal storage circuits (e.g., the addresses of the internal registers and/or memory circuits) 302a; 2) the addresses of the storage resource (e.g., external memory) where, in order to transition to a power state that reduces the voltage of the power domain beneath a critical threshold, the information read from the power domain’s internal storage circuits is to be saved beforehand 302b; and, 3) special accessing meta-data

302c. The special accessing meta-data is a field that indicates any special requirements of the internal information saving process. Examples include sequencing (reading certain internal storage circuits before others) and time delays (reading certain storage circuits only after a certain amount of time has passed after some event).

Although the above discussion has been written with a view toward saving the internal state information of a power domain responsive to entry into a power state that lowers the domain's supply voltage beneath a critical state so as to necessitate the saving of the power domain's internal state, it should be understood that the reverse situation also applies. That is, upon entry to a power state that raises a power domain's voltage from beneath the critical voltage to above it, the power domain's internal state needs to be restored by reading the previously saved information from an (e.g., external) memory device and writing the information back into the power domain's internal registers and/or memory circuits. Note that the tabular information of Fig. 3 can be utilized for both saving and restoration purposes.

Figs. 4a and 4b pertain to a design for streamlining the information state saving and restoring operations for the power domains of a processor in response to the entry/exit of the processor's associated power states. As observed in Fig. 4a, specialized streaming circuitry 460 (e.g., within power management circuitry) embedded on the processor is coupled to a ROM 470 that stores tabularized information, such as that outlined in Fig. 3, used by the streaming circuitry 460 to understand, as a function of which power state is about to be exited and which power state is about to be entered, which internal storage circuits need to have their information stored or restored. The streamlining circuitry 460 also has access to the internal registers and memory circuits within the processor's various power domains, and, has access to the storage resource (e.g., external memory circuitry 408 via memory control hub 404) where the information is written to when being saved, or, read from when being restored. The complex reach of streamlining circuitry 460 into the different power domains cannot be drawn simplistically. Hence only artifacts of it are indicated in Fig. 4a. The other components of the processor observed on Fig. 4a have already been described with respect to Fig. 1.

Fig. 4b shows an embodiment of a methodology performed by the streamlining circuitry 460 of Fig. 4a. According to the embodiment of Fig. 4b, the streamlining circuitry is first made aware of a power state change 401. That is, the streamlining circuitry is made aware of a specific power state being entered and specific power state being exited. The streamlining circuitry then, in an embodiment, looks up information that describes, for both the power state being entered and the power state being exited, which power domains have (or do not have) a sufficient supply voltage to retain their information state 402. Any additional power domains

from the state being exited to the state being entered, in the case of dropping down to a deeper sleep state, corresponds to the specific power domains that should have their information stored. Likewise any additional power domains from the state being exited to the state being entered, when waking up from a deeper sleep state, corresponds to the specific power domains that should have their information restored.

For instance, referring to Fig. 3, when dropping down from the C\_M-X-Y1 state in which all power domains have sufficient supply voltage to retain their internal information state except for the core 201\_1 power domain, to the C\_M-1 power state in which power domains 203, 207, and 201\_1 through 201\_N do not receive a supply voltage sufficient to retain internal state, then, power domains 203, 207 and 201\_2 through 201\_N should have their internal state saved by the streamlining circuitry 460 prior to formal entry to the C\_M-1 state. Contra-wise, when awaking out of the C\_M-X-Y1 state back into the C\_M-1 power state these same power domains correspond to the set of power domains that should have their internal state restored by the streamlining circuitry. In theory, the difference between any two power states as to which power domains are (or are not) provided sufficient supply voltage to retain internal state information should define which power domains should have their state stored or restored for any transition between the two states.

The streamlining circuitry 460 can begin to gain an understanding of this difference, for example, by referring to the two entries in portion of the tabular data of Fig. 3 that correspond to the two power states involved in the power state transition. That is, for instance, if the power state transition is between power states C\_M-X-Y1 and C\_M-1, the streamlining circuitry 460 can refer to the entries for C\_M-X-Y1 and C\_M-1 from portion 301 of Fig. 3 in ROM 470. Here, by referring to these entries in portion 301, the streamlining circuitry 460 will understand that power state C\_M-X-Y1 includes power domain 201\_1, and, power state C\_M-1 includes power domains 203, 207 and 210. In a simpler implementation, all power state transitions involve a same, common power state (e.g., all power state transitions must transition from or to the C0 state). In this case, a single entry can be used to define which power domains are to have their internal state stored (or restored) for any power state transition.

Once the affected power domains are understood for the transition, the streamlining circuitry 460 next looks up information that defines, for each power domain, the addresses of the power domain's internal state, the addresses of the storage resource where the internal state is to be written to in the case of storage (or read from in the case of re-storage), and, any additional meta data that may apply (e.g., sequencing specifics, time delay specifics, etc.) 403. Such information can be obtained, for example, by reference to the particular entry for each power

domain in portion 302 of the tabular information of Fig. 3.

Thus, continuing with the above example, after the look-up into portion 301 of the tabular information in ROM 470 reveals that power domains 201\_1, 203, 207 and 210 are implicated by the power state transition from state C\_M-X-Y1 to C\_M-1, the streamlining circuitry 460 may next look up the entries for each of power domains 201\_1, 203, 207 and 210 in portion 302 of ROM 470. This look up will provide the streamlining circuitry 460 with: 1) the internal address space (whether register or memory) of the internal state information within each of the power domains so the information can be read prior to supply voltage lowering 302a; 2) the corresponding external address space where the information is to be saved to 302b; and, 3) any meta-data associated with the information saving process 302c.

In an effort to specifically define exactly which address space is affected by the power state transition, 403 the returns of the read operations into the ROM are compared for overlap. Here, it is observed that addresses INT\_ADDR\_201\_1 for the power domain associated with the power state that is being departed from (201\_1) overlaps with the addresses of one of the power domains (201) associated with the power state that is being entered. This particular overlap in this particular transition sequence means that power domain 201\_1 need not have its state information saved during the present transition because its state information has already been saved. As such, the streamlining circuitry 460 will recognize that it only needs to save the state information of power domains 201\_2 through 201\_N for power domain 210 for this transition (along with the state information of power domains 203 and 207).

Once any overlap has been resolved so that the set of affected addresses are identified, the state information from the affected power domains is read from their appropriate addresses (generically represented in portion 302a of Fig. 3 as "INT\_ADDR\_") and saved to the corresponding listed address (generically represented in portion 302b in Fig. 3 as "EXT\_ADDR\_") 404. Any associated special conditions associated with the saving process for a particular power domain (generically represented in portion 302c in Fig. 3 as "MD\_") is applied. Some special conditions may be, for instance, to read certain registers before others, timing requirements (e.g., waiting for a period of time before a specific registers is read), application of certain masks, etc. As an example, referring to the entry for power domain 201\_1 in portion 302 of Fig. 3: 1) the entry INT\_ADDR\_201\_1 represents the set of internal addresses of power 201\_1; 2) the entry EXT\_ADDR\_ 201\_1 represents the set of addresses external to power domain 201\_1 where the state information of power domain is to be saved to; and, 3) the entry MD\_201\_1 represents any applicable conditions for the transfer.

Fig. 5 shows a similar process but for restoration of externally saved state information into

a power domain. Notably, the same set of addresses are used during the restoration process – just in opposite order. That is, the EXT\_ADDR addresses are used to read the externally saved information and the INT\_ADDR addresses are used to write the information back into the power domain. The meta data in column 302c of Fig. 3 could be partitioned into two sections: a first section for saving state information externally and a second section for restoring state information internally.

In terms of the restoration process, any overlap of addresses between a power domain of the power state being departed from versus a power domain of a power state being entered into means that the overlapping addresses/domains are to be ignored during the transition (i.e., remain off). Thus, again, the difference between the addresses of the domains of the states involved in the transition determines the set of domains that are affected by the transition.

It is pertinent to point out that the externally saved information of a power domain that is to lose power does not necessarily have to be saved externally from the processor. Conceivably the information could be saved in other storage space of the processor that is to remain powered up after the power state transition. Also, ROM 470 could be implemented as a non volatile ROM. ROM 470 also need not be part of the processor but can be a separate component from it. Component 470 can also be viewed more generally as a memory that need not be a ROM. For example, component could be implemented as a random access memory (RAM), volatile or non volatile, embedded on the processor or external to it.

The streamlining circuitry 460 could be implemented by any of dedicated logic circuitry (e.g., a state machine), a micro-controller, controller or even processor that executes some kind of program code to perform its functions, or, any combination thereof.

Referring back to Fig. 3, the exact architecture of the tabular information can vary from embodiment to embodiment. For example, alternative embodiments may choose to enter all relevant information for a power state (including all addresses and meta data for all its powered down power domains) in a single entry. This avoids having to read the tabular information twice but increases the size of the tabular information. This also permits overlapping power domains of two power states to be identified rather than overlapping address space.

As any of the logic processes taught by the discussion above may be performed with a controller, micro-controller or similar component, such processes may be program code such as machine-executable instructions that cause a machine that executes these instructions to perform certain functions. Processes taught by the discussion above may also be performed by (in the alternative to the execution of program code or in combination with the execution of program code) by electronic circuitry designed to perform the processes (or a portion thereof).

It is believed that processes taught by the discussion above may also be described in source level program code in various object-orientated or non-object-orientated computer programming languages. An article of manufacture may be used to store program code. An article of manufacture that stores program code may be embodied as, but is not limited to, one or more memories (e.g., one or more flash memories, random access memories (static, dynamic or other)), optical disks, CD-ROMs, DVD ROMs, EPROMs, EEPROMs, magnetic or optical cards or other type of machine-readable media suitable for storing electronic instructions. Program code may also be downloaded from a remote computer (e.g., a server) to a requesting computer (e.g., a client) by way of data signals embodied in a propagation medium (e.g., via a communication link (e.g., a network connection)).

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

## CLAIMS

What is claimed is:

1. A processor, comprising:

streamlining circuitry having a first interface to receive information from a memory describing:

- i) respective addresses for internal state information of a power domain;
- ii) respective addresses of a memory where said internal state information is stored when said power domain is powered down;
- iii) meta data for transferring said state information between said power domain and where said internal state information is stored when said power domain is powered down.

2. The processor of claim 1 wherein said streamlining circuitry reads from i) above and writes to ii) above when said power domain is to be powered down as part of a power state transition.

3. The processor of claim 1 wherein said streamlining circuitry reads from ii) above and writes to i) above when said power domain is to be powered up as part of a power state transition.

4. The processor of claim 1 wherein said meta data describes a sequence at which certain items of said internal state information are to be accessed.

5. The processor of claim 1 wherein said meta data describes a time delay before a certain item of said internal state information is to be accessed.

6. The processor of claim 1 wherein said streamlining circuitry provides said memory with an identity of a power state to which said power domain pertains before receiving i); ii) and iii) above.

7. A method, comprising:

receiving the following information at streamlining circuitry:

- i) respective addresses for internal state information of a power domain;
- ii) respective addresses of a memory where said internal state information is stored when said power domain is powered down;
- iii) meta data for transferring said state information between said power domain and

where said internal state information is stored when said power domain is powered down;  
and,

transferring with said streamlining circuitry said state information between said power domain and where said internal state information is stored when said power domain is powered down.

8. The method of claim 7 further comprising said streamlining circuitry reading from i) above and writing to ii) above when said power domain is to be powered down as part of a power state transition.

9. The method of claim 7 further comprising said streamlining circuitry reading from ii) above and writing to i) above when said power domain is to be powered up as part of a power state transition.

10. The method of claim 7 wherein said meta data describes a sequence at which certain items of said internal state information are to be accessed and said method further comprises said streamlining circuitry accessing said items of internal state information in said sequence.

11. The method of claim 7 wherein said meta data describes a time delay before a certain item of said internal state information is to be accessed and said method further comprises said streamlining circuitry imposing said time delay before accessing said certain item of internal state information.

12. The method of claim 7 further comprising said streamlining circuitry providing said memory with an identity of a power state to which said power domain pertains before receiving i); ii) and iii) above.

13. A processor, comprising:

a memory to store the following information for each of a plurality of power states:

i) respective addresses for internal state information of a power domain of a power state;

ii) respective addresses of a memory where said internal state information is stored

when said power domain is powered down;

iii) meta data for transferring said state information between said power domain and where said internal state information is stored when said power domain is powered down; and,

streamlining circuitry coupled to said memory to transfer said state information between said power domain and where said internal state information is stored when said power domain is powered down.

14. The processor of claim 13 wherein said streamlining circuitry reads from i) above and writes to ii) above when said power domain is to be powered down as part of a power state transition.

15. The processor of claim 13 wherein said streamlining circuitry reads from ii) above and writes to i) above when said power domain is to be powered up as part of a power state transition.

16. The processor of claim 13 wherein said meta data describes a sequence at which certain items of said internal state information are to be accessed.

17. The processor of claim 13 wherein said meta data describes a time delay before a certain item of said internal state information is to be accessed.

18. The processor of claim 13 wherein said streamlining circuitry provides said memory with an identity of a power state to which said power domain pertains before receiving i); ii) and iii) above.

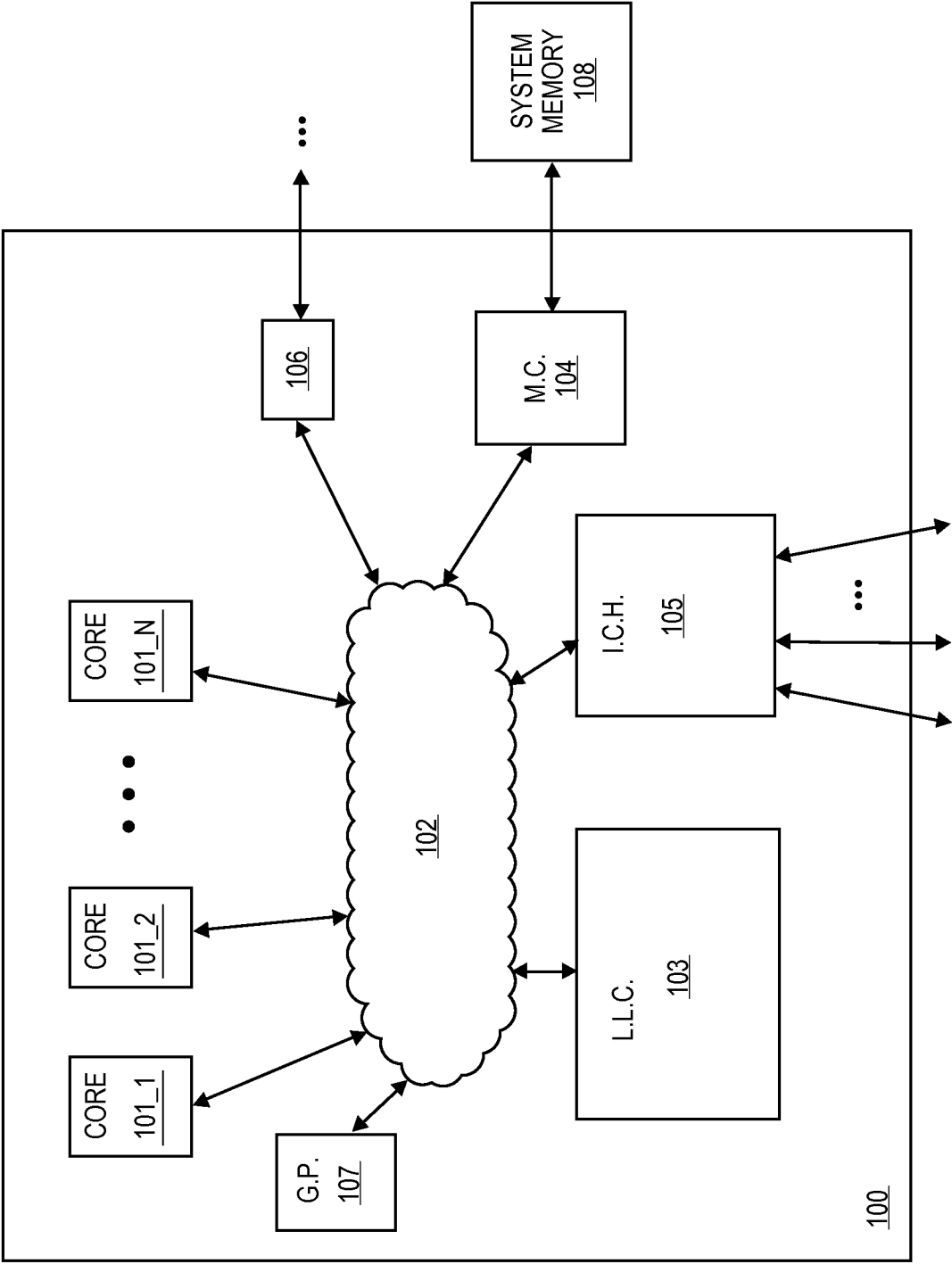
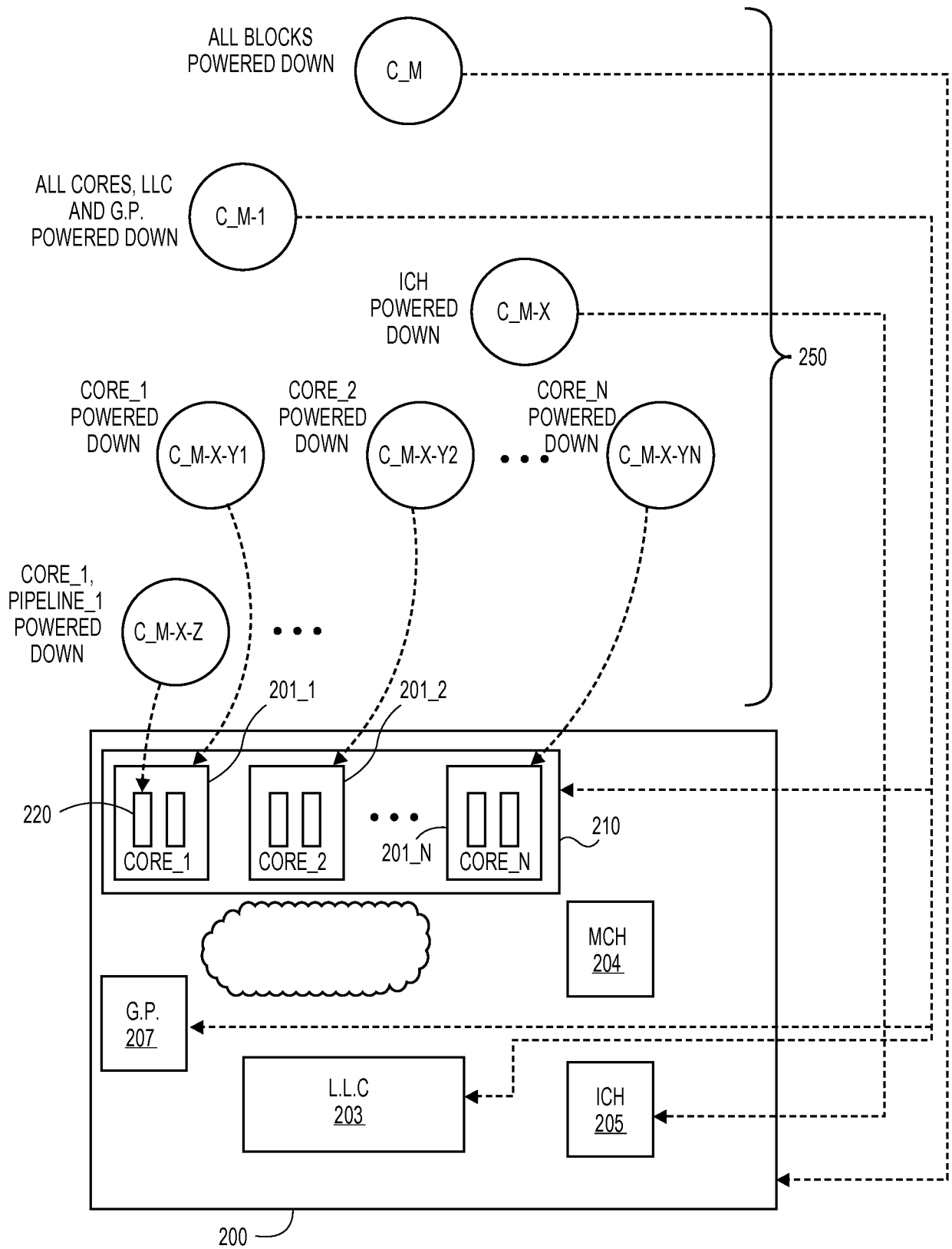


FIG. 1



**FIG. 2**

|             |  |                         |  |
|-------------|--|-------------------------|--|
| POWER STATE |  | DISABLED POWER DOMAIN   |  |
| C_M         |  | 203, 204, 205, 207, 210 |  |
| C_M-1       |  | 203, 207, 210           |  |
| C_M-X       |  | 205                     |  |
| C_M-X-Y1    |  | 201_1                   |  |
| C_M-X-Y2    |  | 201_2                   |  |
| ⋮           |  | ⋮                       |  |
| C_M-X-YN    |  | 201_N                   |  |
| C_M-X-Z     |  | 220                     |  |

← 301

| POWER DOMAIN | INTERNAL PROCESSOR ADDRESS'S OF DOMAIN'S STATE          | EXTERNAL TARGET ADDRESSES FOR DOMAIN'S STATE            | META DATA                             |
|--------------|---------------------------------------------------------|---------------------------------------------------------|---------------------------------------|
| 201_1        | INT_ADDR_201_1                                          | EXT_ADDR_201_1                                          | MD_201_1                              |
| 201_2        | INT_ADDR_201_2                                          | EXT_ADDR_201_2                                          | MD_201_2                              |
| ⋮            | ⋮                                                       | ⋮                                                       | ⋮                                     |
| 201_N        | INT_ADDR_201_N                                          | EXT_ADDR_201_N                                          | MD_201_N                              |
| 203          | INT_ADDR_203                                            | EXT_ADDR_203                                            | MD_203                                |
| 204          | INT_ADDR_204                                            | EXT_ADDR_204                                            | MD_204                                |
| 205          | INT_ADDR_205                                            | EXT_ADDR_205                                            | MD_204                                |
| 207          | INT_ADDR_207                                            | EXT_ADDR_207                                            | MD_207                                |
| 210          | INT_ADDR_201_1<br>INT_ADDR_201_2<br>⋮<br>INT_ADDR_201_N | EXT_ADDR_201_1<br>EXT_ADDR_201_2<br>⋮<br>EXT_ADDR_201_N | MD_201_1<br>MD_201_2<br>⋮<br>MD_201_N |
| 220          | INT_ADDR_220                                            | EXT_ADDR_220                                            | MD_220                                |

← 302

↑

302A

↑

302B

↑

302C

**FIG. 3**

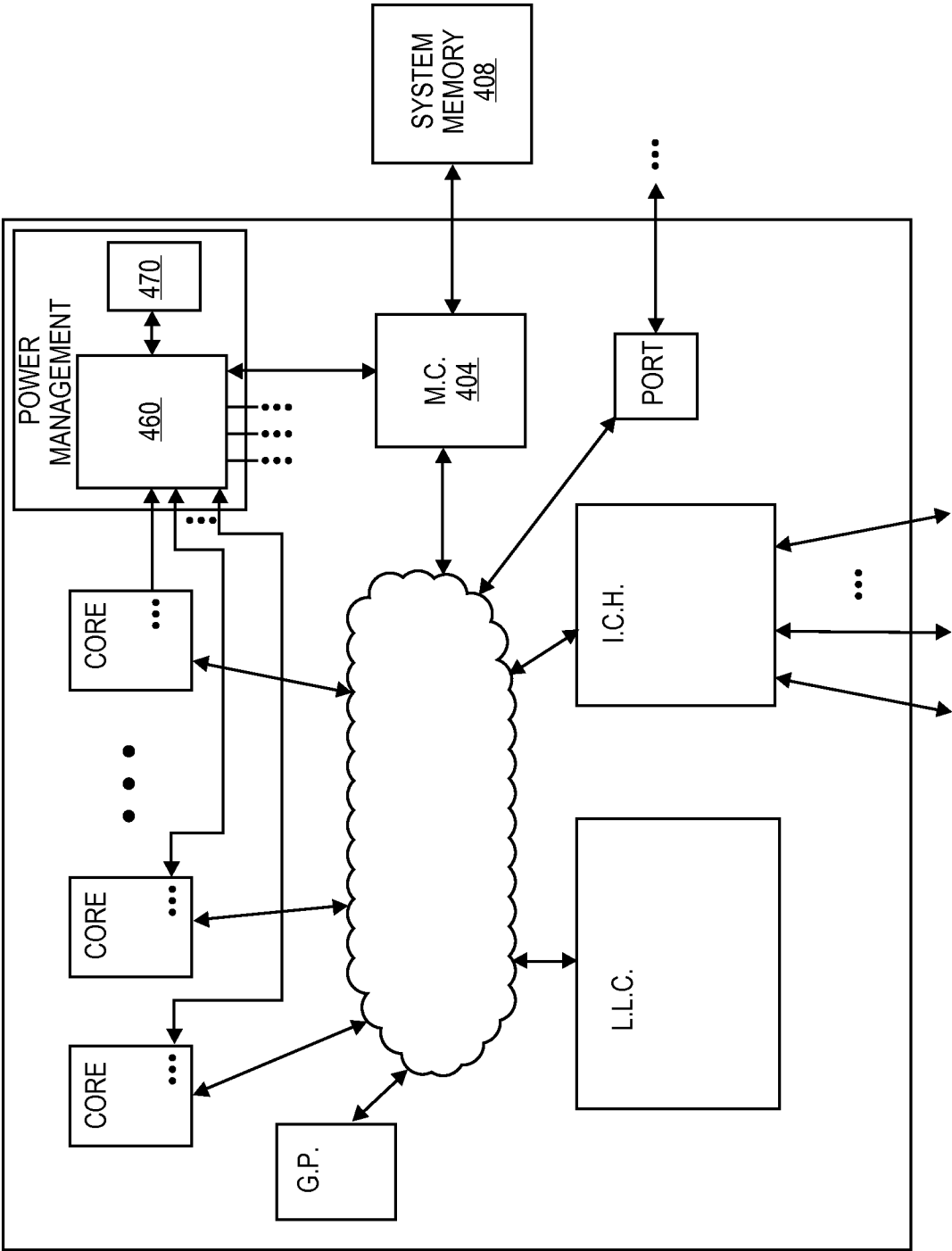
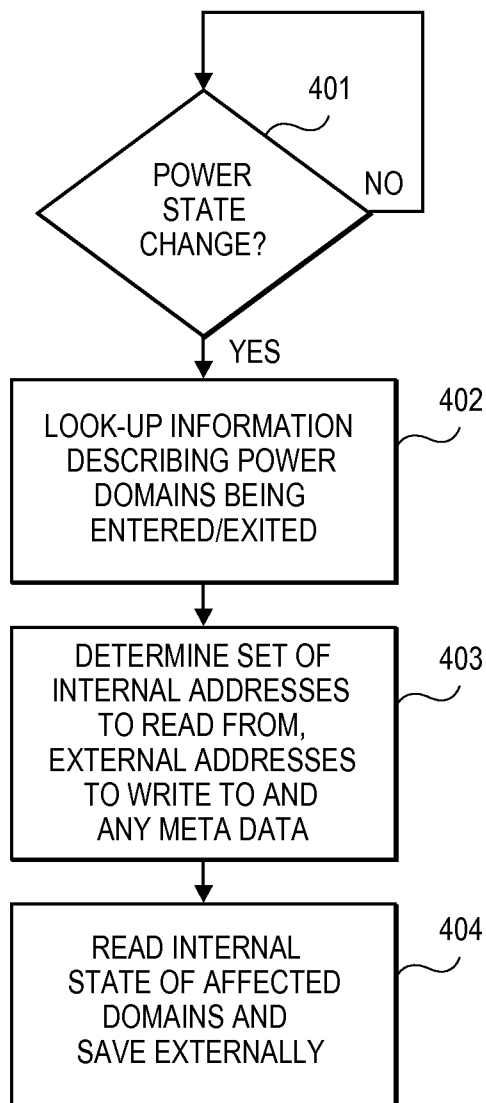
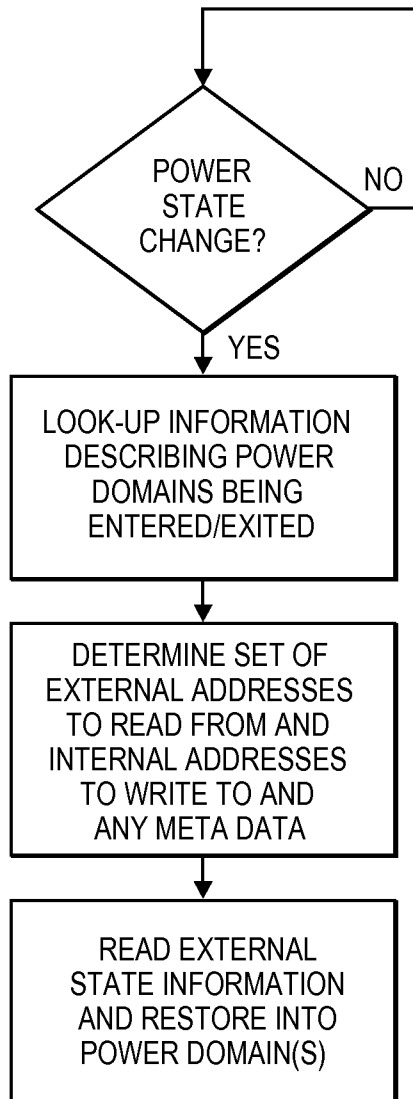


FIG. 4A

**FIG. 4B**

**FIG. 5**

**A. CLASSIFICATION OF SUBJECT MATTER****G06F 13/14(2006.01)i, G06F 13/38(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)

G06F 13/14; G06F 12/06; G06F 17/00; G06F 1/00; G06F 1/32; G06F 13/38

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) &amp; keywords: power state transition, ACPI, internal register, external memory, address

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages                            | Relevant to claim No. |
|-----------|---------------------------------------------------------------------------------------------------------------|-----------------------|
| A         | US 2012-0179927 A1 (INDER M. SODHI et al.) 12 July 2012<br>See paragraphs [0016]–[0044]; and figures 1–3B.    | 1–18                  |
| A         | US 2009-0158067 A1 (DEVADATTA V. BODAS et al.) 18 June 2009<br>See paragraphs [0012]–[0041]; and figures 1–4. | 1–18                  |
| A         | US 2009-0172423 A1 (JUSTIN SONG et al.) 02 July 2009<br>See paragraphs [0019]–[0071]; and figures 1–5.        | 1–18                  |
| A         | US 2011-0055469 A1 (MAHESH S. NATU et al.) 03 March 2011<br>See paragraphs [0009]–[0037]; and figures 1–4.    | 1–18                  |
| A         | US 2002-0038328 A1 (TOSHIKAZU MORISAWA) 28 March 2002<br>See paragraphs [0042]–[0080]; and figures 2–13.      | 1–18                  |



Further documents are listed in the continuation of Box C.



See patent family annex.

\* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&amp;" document member of the same patent family

Date of the actual completion of the international search

21 October 2013 (21.10.2013)

Date of mailing of the international search report

**22 October 2013 (22.10.2013)**

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**INTERNATIONAL SEARCH REPORT**

Information on patent family members

International application No.

**PCT/US2013/048663**

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| US 2009-0158067 A1                        | 18/06/2009          | US 7966506 B2              | 21/06/2011          |
| US 2009-0172423 A1                        | 02/07/2009          | US 7962771 B2              | 14/06/2011          |
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