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Thomson et al.

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(54) **SYSTEM AND APPARATUS FOR CONSOLIDATED DYNAMIC FREQUENCY/VOLTAGE CONTROL**

(56) **References Cited**

U.S. PATENT DOCUMENTS

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6,901,522 B2 5/2005 Buch
7,698,575 B2 * 4/2010 Samson 713/300
8,010,822 B2 8/2011 Marshall et al.
8,024,590 B2 9/2011 Song et al.

(Continued)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

FOREIGN PATENT DOCUMENTS

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 660 days.

EP 1557743 A2 7/2005

OTHER PUBLICATIONS

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(65) **Prior Publication Data**

Primary Examiner — Ji H Bae

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Related U.S. Application Data

(57)

ABSTRACT

(60) Provisional application No. 61/495,861, filed on Jun. 10, 2011.

(51) **Int. Cl.**

G06F 1/32 (2006.01)
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G06F 1/26 (2006.01)
G06F 15/16 (2006.01)
H04L 29/08 (2006.01)
G06F 9/38 (2006.01)

Methods and apparatus for accomplishing dynamic frequency/voltage control between at least two processor cores in a multi-processor device or system include receiving busy, idle and wait, time and/or frequency information from a first processor core and receiving busy, idle, wait, time and/or frequency information from a second processor core. The received busy, idle, wait, time and/or frequency information may be correlated to identify patterns of interdependence. The correlated information may be used to determine dynamic frequency/voltage control settings for the first and second processor cores to provide a performance level that accommodates interdependent processes, threads and processor cores. The correlation of received busy, idle, wait, time and/or frequency information may involve generating a consolidated busy/idle pulse train that can then be used to set the frequency or voltage of each processor core independently.

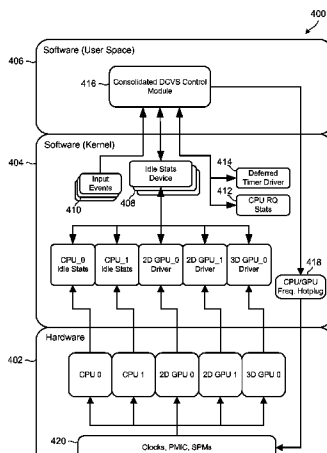
(52) **U.S. Cl.**

CPC **G06F 1/3296** (2013.01); **G06F 1/324** (2013.01); **G06F 1/3228** (2013.01); **G06F 1/3206** (2013.01); **G06F 9/3885** (2013.01); **H04L 67/10** (2013.01); **Y02B 60/1217** (2013.01); **Y02B 60/1285** (2013.01)

(58) **Field of Classification Search**

None
See application file for complete search history.

40 Claims, 11 Drawing Sheets



(56)

References Cited

U.S. PATENT DOCUMENTS

8,069,446 B2 11/2011 Zhao et al.
 8,631,411 B1 1/2014 Ghose
 2005/0022038 A1* 1/2005 Kaushik et al. 713/300
 2006/0026447 A1* 2/2006 Naveh et al. 713/322
 2007/0300227 A1 12/2007 Mall et al.
 2008/0005592 A1 1/2008 Allarey et al.
 2008/0109814 A1 5/2008 Park
 2009/0249094 A1* 10/2009 Marshall et al. 713/320
 2009/0309885 A1 12/2009 Samson et al.
 2009/0328055 A1 12/2009 Bose et al.
 2010/0153761 A1 6/2010 Nishioka
 2010/0241884 A1 9/2010 Barsness et al.
 2010/0299541 A1 11/2010 Ishikawa et al.
 2011/0022871 A1 1/2011 Bouvier et al.
 2011/0078469 A1 3/2011 Therien
 2011/0087909 A1* 4/2011 Kanakogi 713/322
 2011/0088041 A1 4/2011 Alameldeen et al.
 2011/0113270 A1 5/2011 Carter et al.
 2011/0145605 A1 6/2011 Sur et al.
 2011/0145615 A1 6/2011 Rychlik et al.
 2011/0145624 A1 6/2011 Rychlik et al.
 2011/0145824 A1 6/2011 Thomson et al.
 2011/0173617 A1 7/2011 Gargash et al.

2011/0191607 A1* 8/2011 Gunther et al. 713/300
 2011/0191783 A1 8/2011 Le Moal
 2011/0225590 A1 9/2011 Thomson et al.
 2011/0296212 A1 12/2011 Elnozahy et al.
 2012/0131309 A1 5/2012 Johnson et al.
 2013/0060555 A1* 3/2013 Thomson et al. 703/21
 2013/0238912 A1* 9/2013 Priel et al. 713/300

OTHER PUBLICATIONS

Langen, P., et al., "Leakage-Aware Multiprocessor Scheduling", Journal of Signal Processing Systems; for Signal, Image, and Video Technology (Formerly The Journal of VLSI Signal Processing Systems for Signal, Image, and Video Technology), Springer US, Boston, vol. 57, No. 1, May 20, 2008, pp. 73-88, XP019734466, ISSN:1939-8115 abstract paragraph [0004].
 Liu, H., et al., "Combining Coarse-Grained Software Pipelining with DVS for Scheduling Real-Time Periodic Dependent Tasks on Multi-Core Embedded Systems", Journal of Signal Processing Systems; for Signal, Image, and Video Technology (Formerly The Journal of VLSI Signal Processing Systems for Signal, Image, and Video Technology), Springer US, Boston, vol. 57, No. 2, Nov. 26, 2008, pp. 249-262, XP019734482, ISSN:1939-8115 abstract paragraph [0001]—paragraph [0004].

* cited by examiner

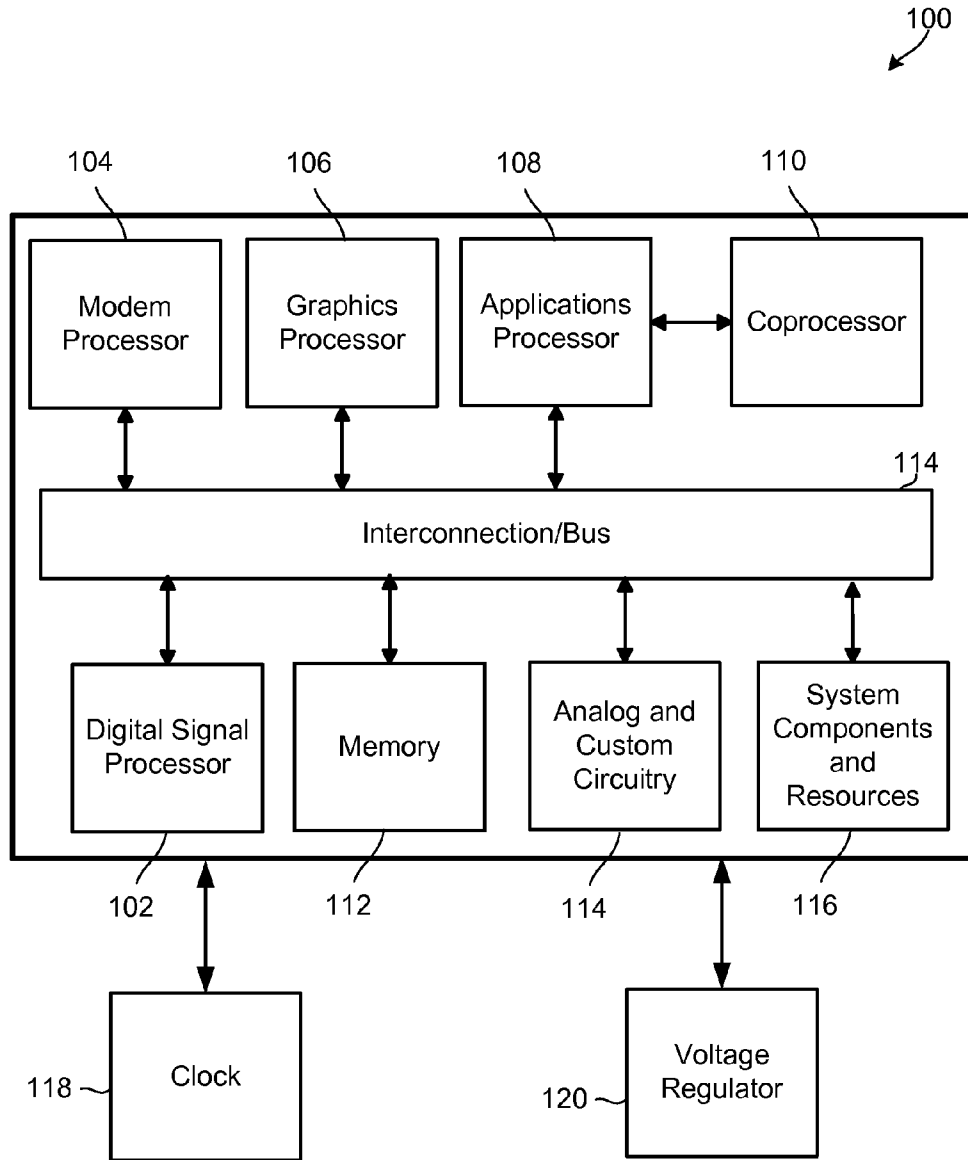


FIG. 1

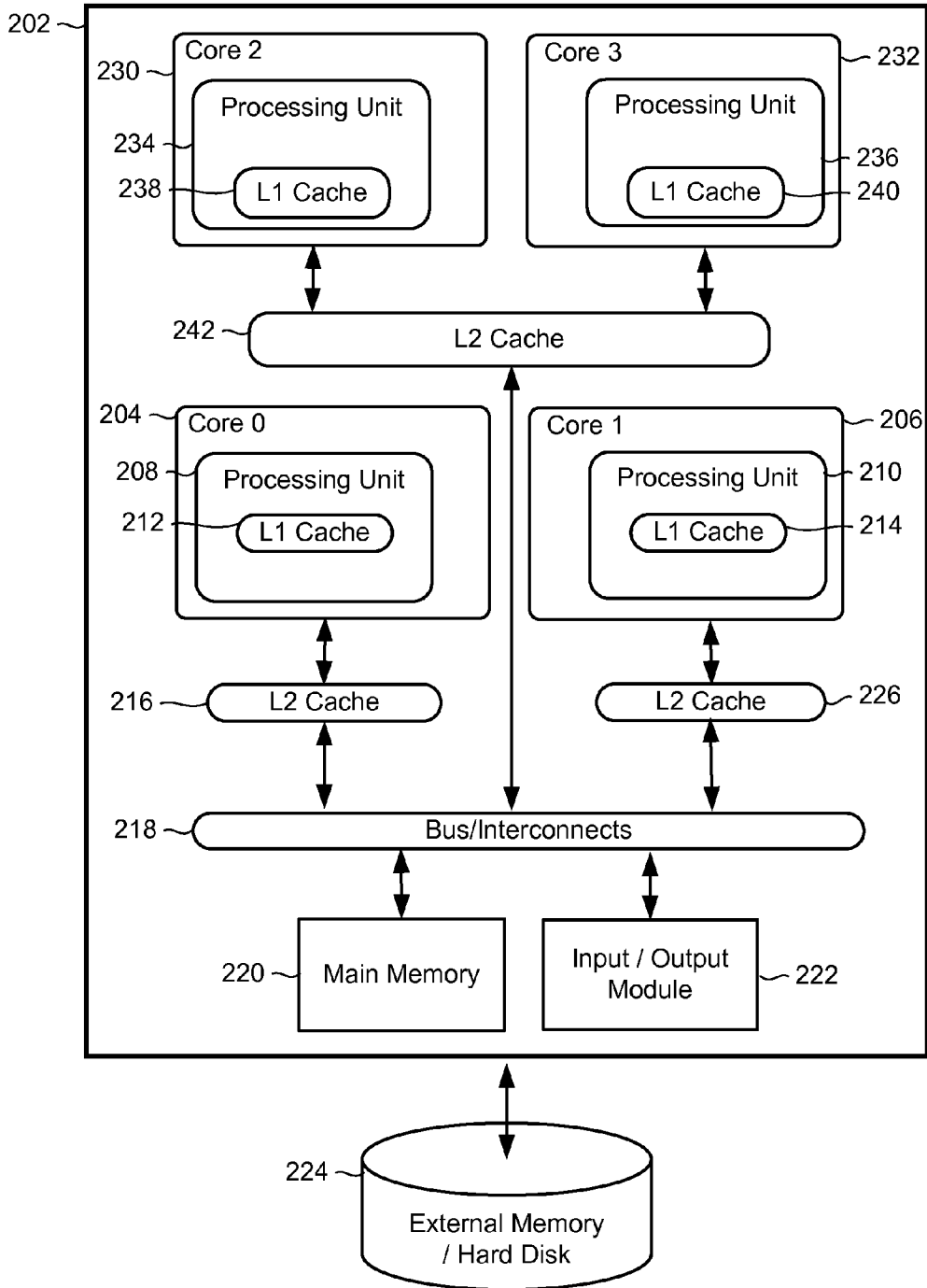


FIG. 2

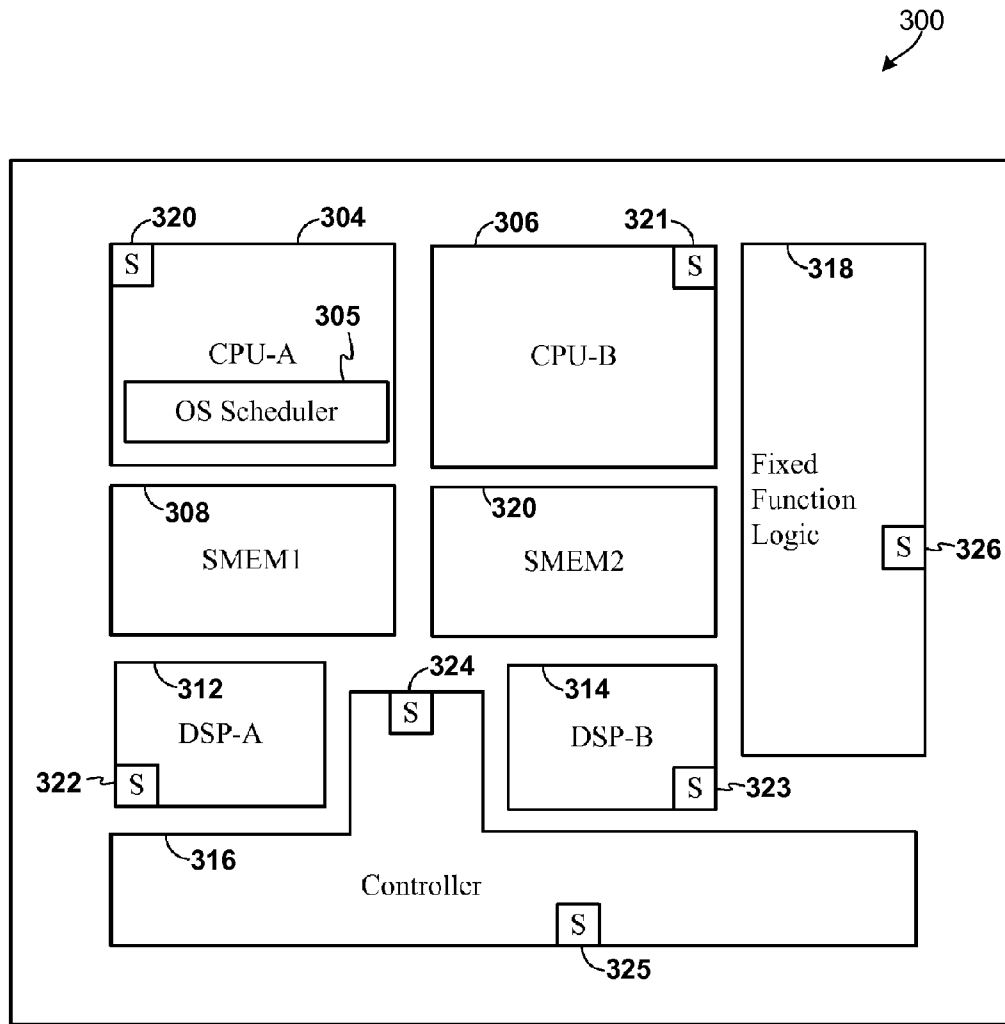


FIG. 3

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