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(54) **DYNAMIC POWER MODE SWITCHING PER RAIL**

(71) Applicant: **Broadcom Corporation**, Irvine, CA (US)

(72) Inventor: **Walid Nabhane**, Long Valley, NJ (US)

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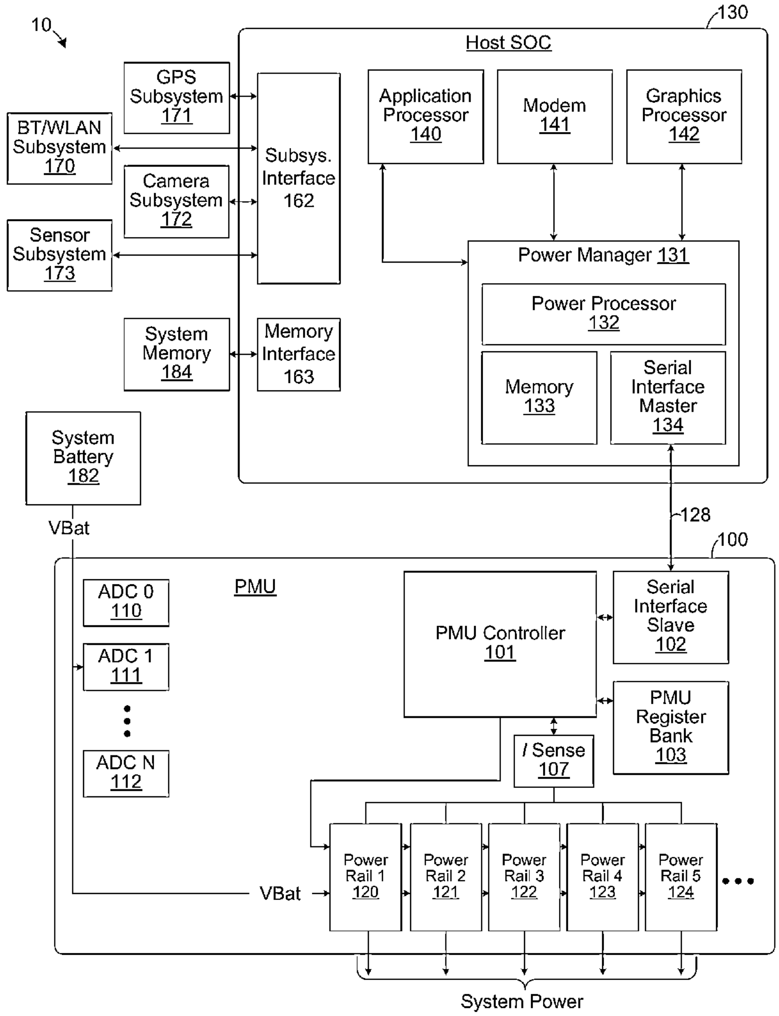
USPC **713/324**; 713/340; 713/320

(57) **ABSTRACT**

Aspects of dynamic power mode switching per rail based on power profiling are described. In one embodiment, an amount of current supplied by at least one of a plurality of power rails is sensed with a current sense circuit. The amount of current is profiled over a period of time and a profile of power consumed is generated and maintained. With reference to the power profile, one or more power-related decisions may be made in a system. One or more power rails may be powered off or placed into low power mode based on various factors, such as the amount of current being consumed per rail, the temperature of certain system components, or an unexpected ongoing consumption of power in the system.



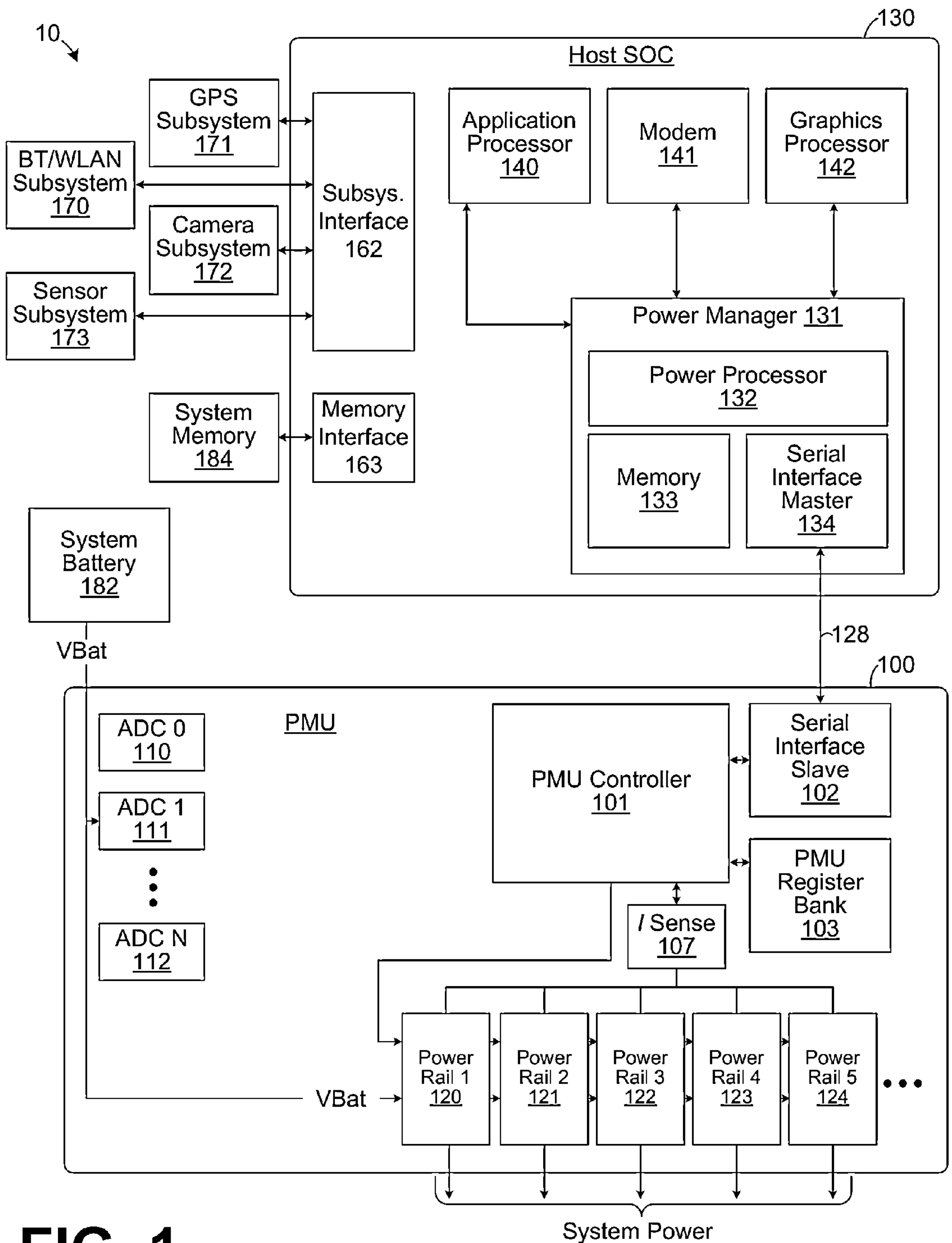

10
130
Host SOC
GPS Subsystem 171
BT/WLAN Subsystem 170
Camera Subsystem 172
Sensor Subsystem 173
Subsys. Interface 162
Application Processor 140
Modem 141
Graphics Processor 142
Power Manager 131
Power Processor 132
Memory 133
Serial Interface Master 134
System Memory 184
Memory Interface 163
System Battery 182
VBat
128
100
PMU
ADC 0 110
ADC 1 111
ADC N 112
PMU Controller 101
Serial Interface Slave 102
PMU Register Bank 103
I Sense 107
VBat
Power Rail 1 120
Power Rail 2 121
Power Rail 3 122
Power Rail 4 123
Power Rail 5 124
System Power

FIG. 1

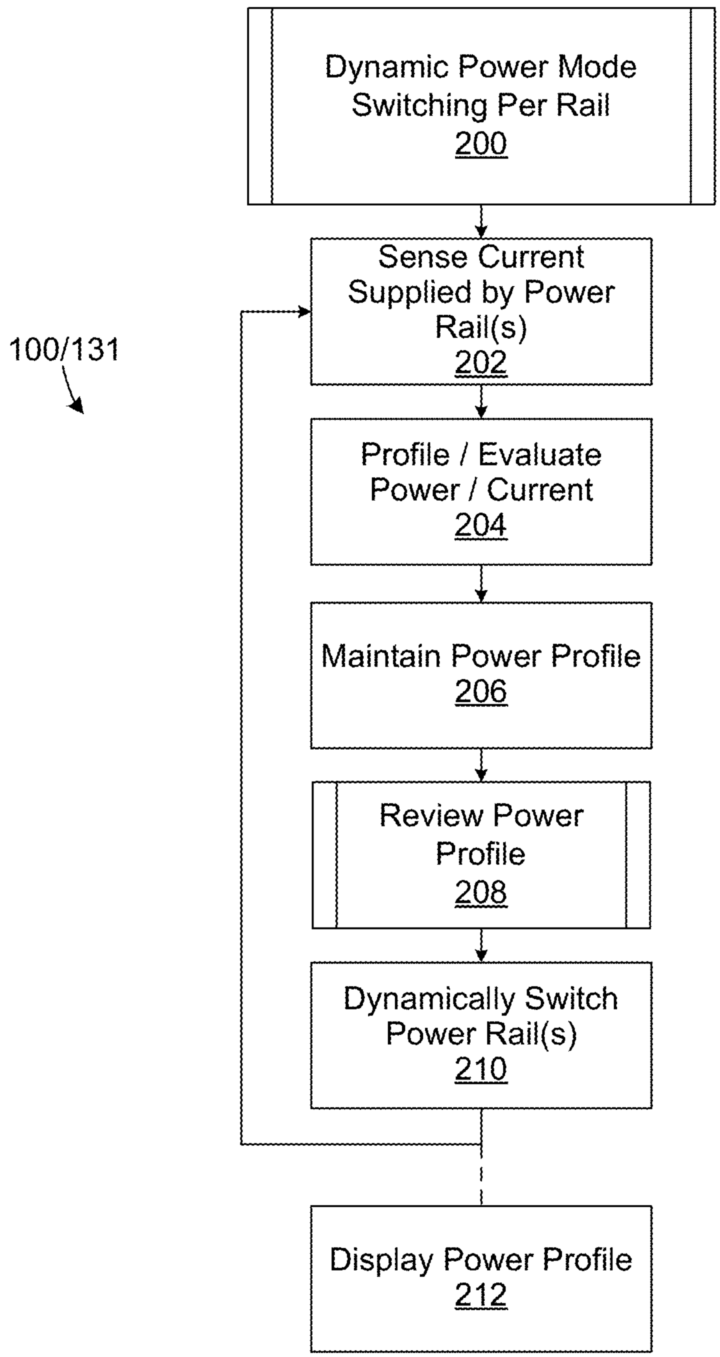

Dynamic Power Mode Switching Per Rail
200
Sense Current Supplied by Power Rail(s)
202
100/131
Profile / Evaluate Power / Current
204
Maintain Power Profile
206
Review Power Profile
208
Dynamically Switch Power Rail(s)
210
Display Power Profile
212

FIG. 2

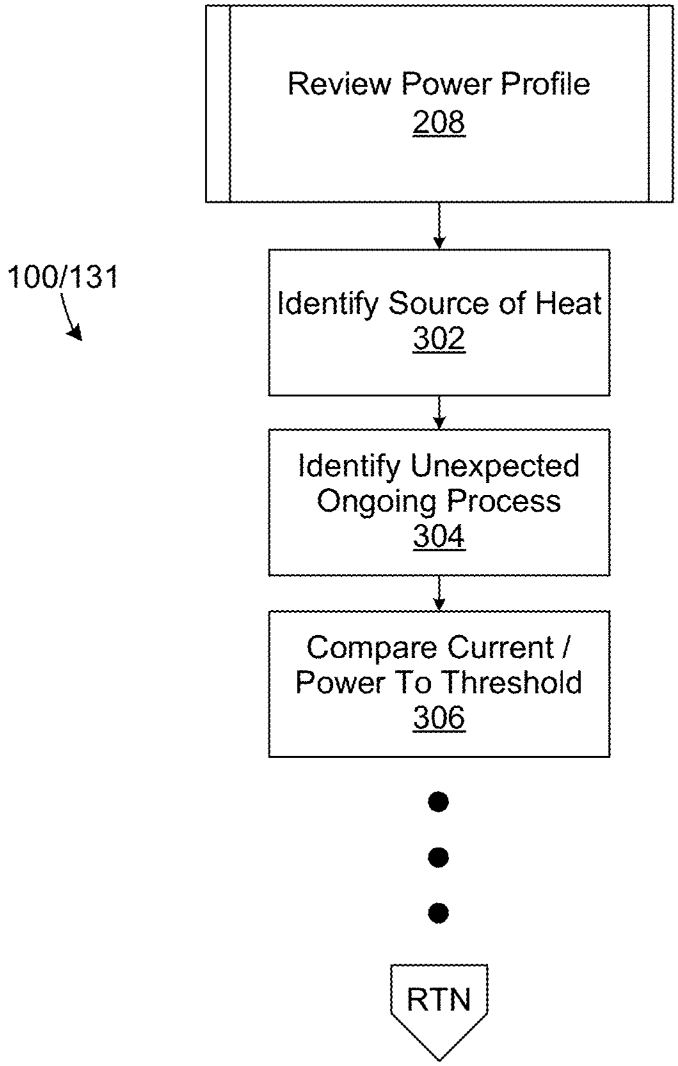

Review Power Profile
208
100/131
Identify Source of Heat
302
Identify Unexpected Ongoing Process
304
Compare Current / Power To Threshold
306
RTN

FIG. 3

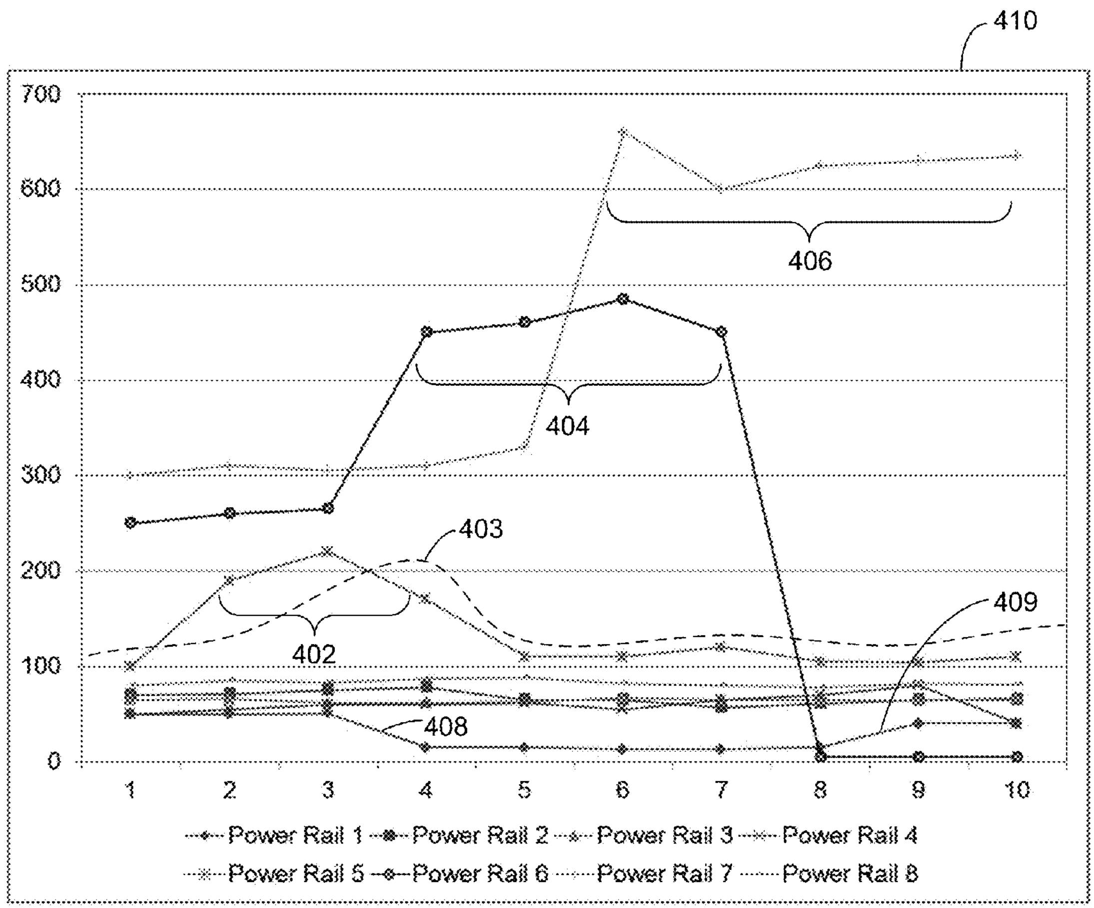

410
700
600
500
400
300
200
100
0
1
2
3
4
5
6
7
8
9
10
406
404
403
402
409
408
Power Rail 1
Power Rail 2
Power Rail 3
Power Rail 4
Power Rail 5
Power Rail 6
Power Rail 7
Power Rail 8

FIG. 4

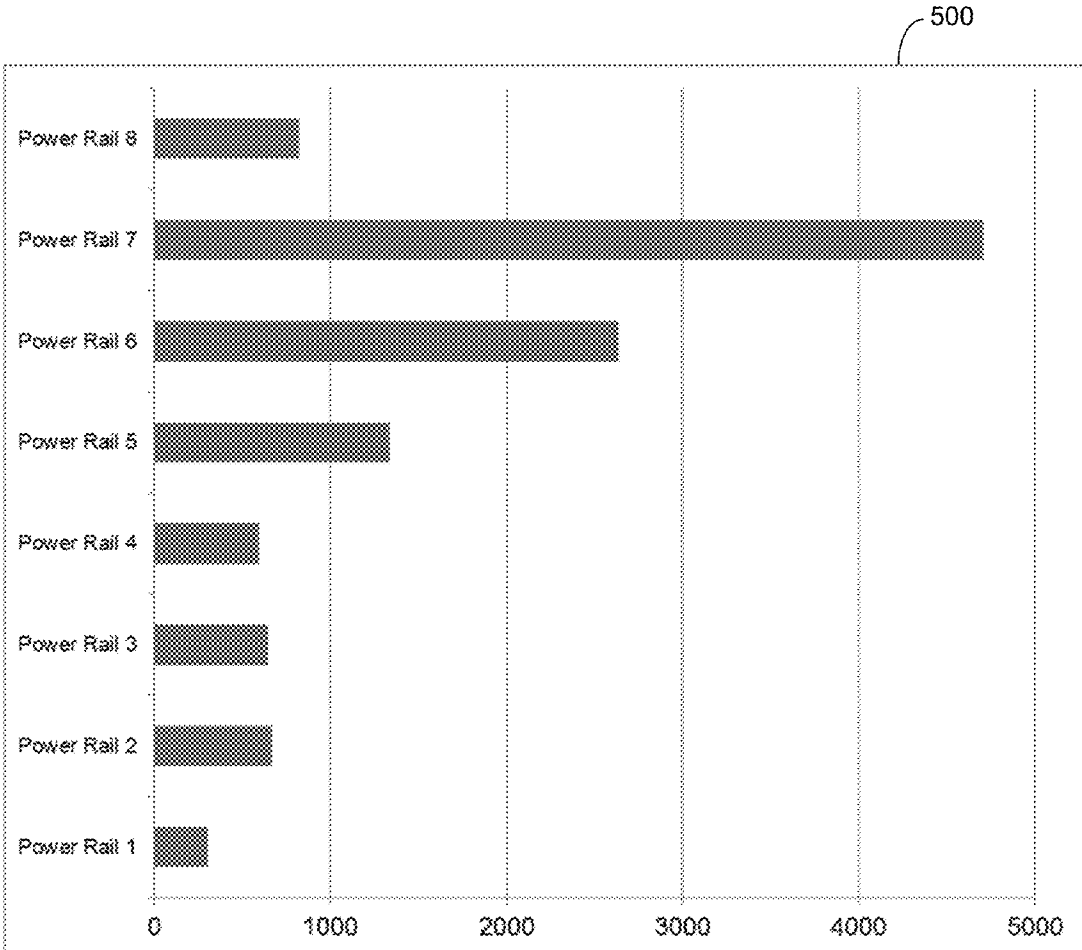

500
Power Rail 8
Power Rail 7
Power Rail 6
Power Rail 5
Power Rail 4
Power Rail 3
Power Rail 2
Power Rail 1
0
1000
2000
3000
4000
5000

FIG. 5

DYNAMIC POWER MODE SWITCHING PER RAIL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of:

[0002] U.S. Provisional Application No. 61/759,470, filed Feb. 1, 2013;

[0003] U.S. Provisional Application No. 61/833,598, filed Jun. 11, 2013;

[0004] U.S. Provisional Application No. 61/834,513, filed Jun. 13, 2013;

[0005] U.S. Provisional Application No. 61/836,327, filed Jun. 18, 2013;

[0006] U.S. Provisional Application No. 61/836,306, filed Jun. 18, 2013;

[0007] U.S. Provisional Application No. 61/836,895, filed Jun. 19, 2013;

[0008] U.S. Provisional Application No. 61/836,886, filed Jun. 19, 2013; and

[0009] U.S. Provisional Application No. 61/836,903, filed Jun. 19, 2013, the entire contents of each of which are hereby incorporated herein by reference.

[0010] This application also makes reference to:

[0011] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4880), titled "Clock Domain Crossing Serial Interface, Direct Latching, and Response Codes" and filed on even date herewith;

[0012] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4890), titled "Power and System Management Information Visibility" and filed on even date herewith;

[0013] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4900), titled "Power Mode Register Reduction and Power Rail Bring Up Enhancement" and filed on even date herewith;

[0014] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4910), titled "Dynamic Power Profiling" and filed on even date herewith;

[0015] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4920), titled "Charger Detection and Optimization Prior to Host Control" and filed on even date herewith; and

[0016] U.S. patent application Ser. No. ______ (Attorney Docket #50229-4940), titled "Enhanced Recovery Mechanism" and filed on even date herewith.

BACKGROUND

[0017] Battery-powered computing systems and devices have been adopted for use in many aspects of daily life. As these systems and devices are more widely adopted and used in place of other computing systems and devices, they are designed to be more flexible and powerful, but are also more complex. With advances in the design of battery-powered computing devices, the availability of sufficient power for the devices continues to be an ongoing concern. For example, each new feature in a battery-powered computing device may require the provision of circuitry that supports a supply of power for the feature.

[0018] In the context of system power management, some battery-powered computing systems include power management processing circuitry that manages the supply of power in the system. Over time, this power management processing circuitry may need to adapt to certain needs in battery-operated systems.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Many aspects of the present disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale, with emphasis instead being placed upon clearly illustrating the principles of the disclosure. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

[0020] FIG. **1** illustrates a system for dynamic power mode switching according to an example embodiment.

[0021] FIG. **2** illustrates a process flow diagram for a process of dynamic power mode switching performed by the system of FIG. **1** according to an example embodiment.

[0022] FIG. **3** further illustrates the process flow diagram for the process of dynamic power mode switching performed by the system of FIG. **1** according to an example embodiment.

[0023] FIG. **4** illustrates a power profile maintained by the system of FIG. **1** and the process of FIGS. **2** and **3** for dynamic power mode switching according to an example embodiment.

[0024] FIG. **5** illustrates a display of a power profile for dynamic power mode switching according to an example embodiment.

DETAILED DESCRIPTION

[0025] In the context of system power management, some battery-powered computing systems include power management processing circuitry that manages the supply of power in the system. Over time, this power management processing circuitry may need to adapt to certain needs in battery-operated systems, such as the need for measurement and profiling of power consumed by various subsystems per power rail.

[0026] Additionally, the need for power management processing circuitry to identify, profile, and evaluate the consumption of per-rail power is now more important, especially as the number of power rails continues to grow and integrated semiconductor circuitry continues to shrink in size. For example, without the ability to identify the consumption of per-rail power, it might not be possible to identify whether a certain subsystem is operating outside its nominal or expected operating parameters. Further, as semiconductor circuitry continues to shrink in size, current leakage, which is variable in part based on temperature, has become a greater problem.

[0027] Although an amount of current leakage may be expected and semiconductor circuitry may be characterized to determine an expected amount of current leakage, it has become more difficult in new systems to rely upon an assumed or expected amount of current leakage. Similarly, it has become more difficult in new systems to rely upon an assumed or expected amount of current consumption for subsystems. When accurate power usage measurements and statistics are unavailable, poor overall power management may result.

[0028] In this context, aspects of dynamic power mode switching per rail based on power profiling are described. In one embodiment, an amount of current supplied by at least one of a plurality of power rails is sensed with a current sense circuit. The amount of current is profiled over a period of time and a profile of power consumed is generated and maintained.

With reference to the power profile, one or more power-related decisions may be made in a system. One or more power rails may be powered off or placed into low power mode based on various factors, such as the amount of current being consumed per rail, the temperature of certain system components, or an unexpected ongoing consumption of power in the system.

[0029] Turning now to the drawings, an introduction and general description of exemplary embodiments of a system is provided, followed by a description of the operation of the same.

[0030] I. System Introduction

[0031] FIG. **1** illustrates a system **10** for dynamic power mode switching according to an example embodiment. The system **10** may embody a computing device that includes a number of general and/or specific purpose circuits, processing circuits, processors, registers, memories, sensors, displays, etc. In one embodiment, the system **10** may embody a handheld or portable computing device which is powered from charge stored in a battery. In various embodiments, the system **10** may be embodied as part of a cellular telephone, tablet computing device, laptop computer, or other computing device. Alternatively, because the embodiments described herein are not limited to use in handheld or portable computing devices, the system **10** may be embodied as part of a desktop or set top computing device, for example. Although not illustrated in FIG. **1**, it should be appreciated that the system **10** may include one or more displays, microphones, speakers, buttons, indicator lights, haptic feedback elements, memory card readers, etc.

[0032] Among other elements, the system **10** includes a power management unit (PMU) **100**, a host system-on-chip (SOC) **130**, a system battery **182**, and a system memory **184**. The system **10** also includes certain subsystems such as a bluetooth / wireless local area network (WLAN) subsystem **170**, a global positioning system (GPS) subsystem **171**, a camera subsystem **172**, and a sensor subsystem **173**. The subsystems **170-173** are representative subsystems which may be included as elements of the system **10**, and other subsystems are within the scope and spirit of the embodiments described herein. It is noted that, just as the host SOC **130** requires power for operation, each of the subsystems **170-173**, the system memory **184**, and other elements and circuits of the system **10** depend on power for operation. As discussed below, this power may be supplied by and under the control of the PMU **100**.

[0033] The system battery **182** may be embodied as any rechargeable battery suitable for the application, such as a lithium-ion, nickel-metal-hydride, or other battery variant, without limitation. The system memory **184** may be embodied as a volatile and/or non-volatile random access memory or combination thereof. The system memory **184** may store computer-readable instructions thereon that, when executed by one or more of the processors **140-142** of the host SOC **130**, for example, direct the processors **140-142** to execute various aspects of the embodiments described herein.

[0034] In general, the PMU **100** controls and/or facilitates control of the distribution of power from the system battery **182** to the elements of the system **10**, such as the host SOC **130**, the subsystems **170-173**, and the system memory **184**, for example. As further described below, depending upon the operating state of the system **10** and/or other factors, the PMU **100** may control the distribution of power to one or more elements of the system **10**, or the PMU **100** may receive instructions to control the distribution of power to one or more elements of the system **10**.

[0035] Among other elements, the PMU **100** includes a PMU controller **101**, a serial interface slave **102**, a PMU register bank **103**, a current (*I*) sense circuit **107**, a number **0**-N of analog-to-digital (ADC) circuits **110-112**, and a number of power rail circuits **120-124**. It is noted that FIG. **1** illustrates a representative example of elements of the PMU **100**, and it should be appreciated that the PMU **100** may include other elements in various embodiments. For example, the PMU **100** may include several additional power rails in addition to those illustrated in FIG. **1**, to provide power to each element in the system **10**, as needed.

[0036] In general, each of the power rails **120-124** includes a low dropout regulator (LDO) or switching type of power rail. An LDO power rail includes a linear voltage regulator that operates suitably even with a relatively low differential input vs. output voltage. A switching power rail includes an active switching circuit that charges and/or discharges reactive circuit elements to boost voltage or current, for example. It should be appreciated that an LDO or switching power rail is selected for each of the power rails **120-124** depending upon certain factors such as output voltage, input/output differential voltage, sourced current, power dissipation, cost, etc.

[0037] Among other elements, the host SOC **130** includes general and/or application specific processors. In FIG. **1**, the host SOC **130** includes a power manager **131**, an application processor **140**, a modem **141**, and a graphics processor **142**. In various embodiments, the host SOC **130** may omit one or more of the processors **140-142** or include processors in addition to the processors **140-142**. The host SOC **130** also includes a subsystem interface **162** and memory interface **163**. The subsystem interface **162** and the memory interface **163** electrically and communicatively couple the subsystems **170-173** and the system memory **184** to the host SOC **130** and, particularly, to one or more of the processors **140-142**.

[0038] The application processor **140** may be embodied as a general purpose processor for executing various applications. For example, the application processor **140** may execute an underlying operating system along with applications such as e-mail, short message service (SMS), telephone, camera, web-browser, and other applications, without limitation. As compared to the PMU **100** and/or the power manager **131**, the application processor **140** may consume relatively more power during operation. The modem **141** may include a cellular-based (or similar) communications processor for the communication of data wirelessly in connection with radio-frequency front end circuitry, and the graphics processor **142** may include a processor for driving a display of the system **10**.

[0039] The power manager **131** includes a power or system power control processor **132**, a memory **133**, and a serial interface master **134**. The power processor **132** may be embodied as a relatively small and low power processor or processing circuit for interfacing with the PMU **100** via a serial interface **128**. In one embodiment, the serial interface master **134** of the power manager **131** controls the serial interface **128**, although the PMU **100** may control the serial interface **128** in other embodiments. The memory **133** stores computer-readable instructions for execution by the power processor **132**.

[0040] II. System Operation

[0041] With reference to the elements of the system **10** introduced above, aspects of the operation of the system **10** are described below.

[0042] A. PMU Operation

[0043] The PMU **100** may be designed, adapted, and configured to perform operations that support the host SOC **130**, the subsystems **170-173**, the system memory **184**, and other elements of the system **10**. As one operational aspect of the PMU **100**, the PMU **100** supplies power from the system battery **182** to other elements of the system **10** via the power rails **120-124**. Further, when the system **10** is coupled to charging power via the system bus **180**, the PMU **100** may charge the system battery **182**. In certain aspects, the PMU **100** may monitor the voltage VBat of the system battery **182** and store a value of the voltage in the PMU register bank **103**.

[0044] In other operational aspects of the PMU **100**, the PMU controller **101** coordinates and controls the operations of the PMU **100**. The PMU controller **101** may be embodied as a general or specific purpose circuit, processing circuit, processor, state machine, etc. The PMU controller **101** interfaces with the serial interface slave **102** to communicate with the host SOC **130** over the serial interface **128**, interfaces with the power rail circuits **120-124** to control and sense power that is supplied to the system **10**, and interfaces with the PMU register bank **103** to store and access data associated with the status of the PMU **100** and the system **10**.

[0045] The serial interface slave **102** comprises one end of the serial interface **128** that facilitates communication between the PMU **100** and the host SOC **130**. Among various modes and states of operation of the system **10**, the serial interface **128** is relied upon to communicate data between the PMU **100** and the host SOC **130**.

[0046] The current sense circuit **107** may be relied upon by the PMU **100** to determine an amount of current or power being supplied by at least one of a plurality of power rails **120-124**. In certain embodiments, current sense circuit **107** may determine an amount of current being supplied by each of the power rails **120-124**. Data on the amount of current supplied by one or more of the power rails **120-124** is relied upon as power profile data by the system **10**. This power profile data may be gathered by the current sense circuit **107**, as further described below, at the direction of the PMU controller **101** (and/or the power manager **131**) and stored in the PMU register bank **103**. The power profile data may also be communicated by the PMU **100** to the power manager **131** and/or the application processor **140** of host SOC **130** for further evaluation and processing.

[0047] The ADCs **110-112** may be relied upon to determine the voltage VBat of the system battery **182**, the temperature of components in the system **10**, etc. Particularly, the ADCs **110-112** may convert analog values of the VBat voltage, and voltages representative of the temperature of components in the system **10**, into digital values for processing and/or storage by the PMU **100**. These digital values include examples of power and management system status data that may be relied upon by the power manager **131** when determining whether to power on or power off certain power rails, as described below.

[0048] In one aspect, the current sense circuit **107** relies upon representative-scale replica power rail circuits to sense an amount of current being supplied by each of the power rails **120-124**. By configuring the current sense circuit **107**, the amount of current may be sensed from time to time or over a period of time as directed by the PMU controller **101** and/or the power manager **131**. In general, the power profile data may be representative of operational aspects of the system **10**.

[0049] B. Host SOC Operation

[0050] The host SOC **130** may be generally embodied as a full system-on-chip semiconductor device. In this sense, the host SOC **130** integrates various general and/or application specific processors and processing circuits into a single integrated circuit package, reducing space. Overall, the power manager **131** of the host SOC **130** supports the host SOC **130** and the power requirements of the host SOC **130**.

[0051] In the context of power usage by the host SOC **130**, it is noted that each of the power manager **131**, the application processor **140**, the modem **141**, and the graphics processor **142** may be powered by a respective power rail of the PMU **100** in the system **10**. For example, in the embodiment illustrated in FIG. **1**, the power manager **131** may be powered by the power rail **1 120**, and the application processor **140** may be powered by the power rail **2 121**. Other elements and/or subsystems in the system **10** and within the host SOC may also be powered, respectively, by one or more power rails of the PMU **100**. Each of the power rails **120-124** (and others) may be electrically coupled from the PMU **100** to the host SOC **130** and to other subsystems in the system **10** by respective power traces in the system **10** and power pins or pads of the PMU **100** and the host SOC **130**.

[0052] According to aspects of the embodiments described herein, power manager or power manager circuit **131** of the host SOC **130** may request and retrieve power profile data stored by the PMU **100**. The power manager circuit **131** may further evaluate the power profile data stored in the PMU **100**, while coordinating power consumption by the host SOC **130** and/or the subsystems **170-173** in connection with control of the power rails **120-124** of the PMU **100**.

[0053] The power manger **131** may retrieve and evaluate the data on the amount of current or power sourced by each of the power rails **120-124** over time. Additionally, the power manger **131** may retrieve and evaluate voltages output by each of the power rails **120-124** over time. Using the current and voltage data, the power manger **131** may calculate the amount of power sourced by each of the power rails **120-124**.

[0054] In this context, the power manager **131** may evaluate the amount of current, voltage, or power sourced by one or more of the power rails **120-124** over a period of time and maintain a power profile of power consumed by one or more system elements in the system. In connection with other system status data from the PMU **100**, the power manger **131** may also identify one or more system elements as a source of heat in the system **10** based on the power profile. In response, the power manger **131** may change an output voltage of or power down a power rail associated with the system element which is the source of heat.

[0055] In another aspect, the power manager **131** may identify an unexpected ongoing processing status or state of a processor or other system element in the system **10** based on an amount of current identified in the power profile over a certain period of time. In certain cases, the identification of the unexpected ongoing processing status or state may be helpful to diagnose a system problem or troubleshoot hardware or software problems. Additionally, as further described below, the power manager **131** may also set the operating mode of one or more power rails over time based on whether an amount of current or power sourced by the one or more power rails is less than or approaches a threshold of current.

[0056] In connection with the evaluation and review of power profile data, the power manager **131** may operate with the PMU **100** to power up and power down power rails in the system **10** in one or more groups or individually, as needed, over time. It is noted that, in certain embodiments, the host SOC **130** (including the power manager **131**) and the PMU **100** may be combined in an integrated circuit. In this case, the serial interface **128** may be omitted and/or the power manager **131** and the PMU controller **101** may be combined.

[0057] Turning to FIGS. **2** and **3**, process flow diagrams illustrating example processes performed by the system **10** for dynamic power mode switching per rail are illustrated. While the process flow diagrams are generally described as being performed by the PMU **100** and/or the power management processor **131** in the system **10** of FIG. **1**, it is noted that other systems may perform the illustrated processes. That is, in various embodiments, systems similar to the system **10** may perform the processes illustrated in FIGS. **2** and **3**.

[0058] In certain aspects, the flowcharts of FIGS. **2** and **3** may be considered to depict example steps performed by the system **10** according to one or more embodiments. Although the process diagrams of FIGS. **2** and **3** illustrate an order, it should be understood that the order may differ from that which is depicted. For example, an order of two or more elements in the process may be scrambled relative to that shown, performed concurrently, or performed with partial concurrence. Further, in some embodiments, one or more of the elements may be skipped or omitted within the scope and spirit of the embodiments described herein.

[0059] FIG. **2** illustrates a process flow diagram for a process **200** of dynamic power mode switching performed by the system **10** of FIG. **1** according to an example embodiment. Starting at reference numeral **202**, the process **200** includes sensing an amount of current or power supplied by at least one of a plurality of power rails. For example, the current sense circuit **107** in the PMU **100** (FIG. **1**) may sense the amount of current supplied by one of more of the power rails **120-124** from time to time or periodically over time. In one embodiment, the current sense circuit **107** may sense the amount of current supplied by each of the power rails **120-124** from time to time or periodically over time. The sensed current values are converted to digital values and stored by the PMU **100** in the PMU register bank **103**. Thus, the amount of current sourced by the power rails **120-124** (and any others) is available as power profile data, for retrieval, reference, and evaluation by the PMU controller **101** and/or the power manager **131**.

[0060] Continuing to reference numeral **204**, the process **200** includes profiling and/or evaluating the amount of power or current supplied by the power rails **120-124** over a period of time. It is noted that the period of time for the evaluation may vary among embodiments. For example, the period of time may range from substantially no time (e.g., instantaneous) to microseconds, milliseconds, seconds, minutes, hours, etc., without limitation. In certain aspects, the profiling may include retrieving power profile data stored in the PMU register bank **103** from time to time as it is updated by the PMU **100**. The power profile data retrieved from the PMU register bank **103** may include an amount of current supplied over time by each of the power rails **120-124**, a voltage output over time by each of the power rails **120-124**, system temperature data taken over time, and other system parameters such as the voltage VBat of the system battery **182**. The profiling at reference numeral **204** may also include aggregating and organizing the retrieved data. In one embodiment, the data may be aggregated and organized by the power processor and stored, at least in part, in the memory **133** of the power manager **131**.

[0061] At reference numeral **206**, the process **200** includes generating and/or maintaining a power profile of power consumed by one or more of a plurality of system elements in the system **10** based on the profiling performed at reference numeral **204**. As further described below, the power profile may be maintained for one or more system elements in the system **10**, in association with one or more corresponding ones of the power rails **120-124** that supply power to the system elements.

[0062] With reference to FIG. **4**, further details on a maintaining a power profile are described. FIG. **4** illustrates a power profile **410** maintained by the system **10** of FIG. **1** according to an example embodiment. FIG. **4** generally illustrates current sourced or power consumed in the system **10** with reference to example power rails **1-8**, individually, and is representative of power consumed by elements or subsystems of the system **10**. Power consumed or current sourced by the power rails **120-124** in the system **10** may be represented among the data plotted for one or more of the power rails **1-8** in FIG. **4**. The y-axis in FIG. **4** may be representative of current, volts, or power, for example, in mA, mV, or mW, for example, and the x-axis in FIG. **4** may be representative of time.

[0063] Referring back to FIG. **2**, at reference numeral **208**, the process **200** includes reviewing the power profile generated and/or maintained at reference numeral **206**. In various aspects, the reviewing at reference numeral **208** includes comparing power sourced by one or more power rails to one or more thresholds, identifying correlations between power consumption and heat, and/or identifying unexpected ongoing processes, for example, among other processes. That is, at reference numeral **208**, a further review and analysis of the power profile is performed. Further details regarding reviewing the power profile at reference numeral **208** are described below with reference to FIG. **3**.

[0064] At reference numeral **210**, the process **200** includes dynamically switching one or more power rails based on the review of the power profile at reference numeral **208**. For example, the power manager **131** may set one or more of the power rails **120-124** into low power mode at reference numeral **210**, as necessary. Additionally or alternatively, the power manger **131** may power off or power on one or more of the power rails **120-124**, etc. In this context, it is noted that the operating parameters for any one of the power rails **120-124** (and any others) may be set, modified, and updated individually, based on the review performed at reference numeral **208**. In other scenarios, operating settings for an entire group of the power rails **120-124** may be quickly modified to low power mode, normal mode, etc., by one command to the PMU **100**. Thus, the dynamic switching at reference numeral **210** may be performed in a manner which is flexible, with reference to power data for each individual power rail in the system **10**. It is noted that the process **200** may return to reference numeral **202** as an iterative process of dynamic power mode switching.

[0065] In other aspects, at reference numeral **212**, the process **200** may include displaying a power profile as an amount of power consumed by one or more system elements of the system **10** over time. In this context, FIG. **5** illustrates display **500** that may be displayed as representative of amount of power consumed by one or more system elements of the system **10** over time. The display **500** may be rendered on a physical display of the system **10**, at the request of a user. In FIG. **5**, the x-axis may be representative of mA or mW hours or minutes, for example. FIG. **5** generally illustrates power consumed in the system **10** with reference to example power rails **1-8**, individually. In practice, the each of the power rails on the display **500** may be identified by system element or subsystem. As opposed to other displays of power information that may be estimated by battery-powered systems, the display **500** may be generated by the system **10** based on actual data sensed by the current sense circuit **107** for current sourced by individual power rails. The display **500** may also be generated using a combination of current and voltage data for respective power rails over time. Thus, the display **500** may provide an accurate real-time display of power usage in battery-powered systems.

[0066] Turning to FIG. **3**, further aspects of reviewing, as performed at reference numeral **208** of the process **200** of FIG. **2**, are described. At reference numeral **302**, reviewing at reference numeral **208** may include identifying a system element as a source of heat in the system **10**. For example, referring to FIG. **4**, the power manager **131** may correlate the relatively increased power consumption **402** for the power rail **5** as being associated with an increase in temperature **403** (dashed line) measured by the PMU **100**, based on the overlapped or coincident timing of the increased temperature **403** with the increased power consumption **402**. By system design, because the power manager **131** and/or the PMU **100** identifies the power rail **5** as being associated with a certain element or subsystem of the system **10**, the power manager **131** and/or the PMU **100** may correlate the element or subsystem associated with the power rail **5** (e.g., the BT/WLAN subsystem **170**, etc.) as being the cause of the increase in temperature. In this manner, the cause or root of increased temperatures in the system **10** may be more accurately identified. Further, if necessary, the power rail **5** may be powered off, set to an alternative voltage, etc., by the power manager **131** to prevent damage to the system **10**, for example.

[0067] Referencing FIG. **3** again, at reference numeral **304**, the reviewing at reference numeral **208** includes identifying an unexpected ongoing processing status or state of an element in the system **10** based on the amount of current. Referring again to FIG. **4**, the increased and ongoing power consumptions **404** and **406** may be identified at reference numeral **208** by the power manager **131** as unexpected states of power consumption under certain circumstances. For troubleshooting software and/or hardware, for example, abnormal or unexpected power consumption, such as the power consumptions **404** and **406**, may be identified and addressed by the power manager **131**. The system or subsystem element associated with the power consumption **404** and the power rail **6**, for example, may be reset or powered down, as necessary, to address the problem as illustrated in FIG. **4**.

[0068] At reference numeral **306** of FIG. **3**, the reviewing at reference numeral **208** includes comparing an amount of current or power to a threshold. In FIG. **4**, for example, the amount of current sourced by the power rail **1** is compared to a current threshold. As one example, the current sourced by the power rail **1** may be compared to a 20 mA threshold by the power manager **131**, although use of any current or power threshold values suitable for the application are within the scope and spirit of the embodiments described herein. In turn, when the amount of current sourced by the power rail **1** is less than the 20 mA threshold (e.g., at reference **408** in FIG. **4**), the settings of the power rail **1** may be dynamically switched to place the power rail **1** into a low power mode of operation at reference numeral **210** of FIG. **2**. Here, it is noted that switching the power rail **1** into the low power mode of operation may help conserve power for the system **10**. Particularly, because the power rail **1** is sourcing such a low amount of current, at least part of the circuitry that supports the power rail **1** may be turned off until more current is demanded.

[0069] In other systems, certain power rails are placed into low power mode depending upon the state of the system, without actual knowledge of measured current consumption. According to aspects of the embodiments described herein, however, power rails may be set into low power mode whenever they are not needed for high current sourcing, based on the power profile **410** maintained by the power manager **131**.

[0070] As another example of comparing current or power to a threshold at reference numeral **306**, when the amount of current sourced by the power rail **1** approaches the 20 mA threshold (e.g., at reference **409** in FIG. **4**), the settings of the power rail **1** may be dynamically switched at reference numeral **210** of FIG. **2**, to place the power rail **1** bank into a normal mode of operation. Thus, the power rail **1** may be dynamically switched between low power and normal modes of operation based on actual power demands in the system **10**. In certain aspects, the power rail **1** may be dynamically switched back to a normal power mode of operation by the power manager **131** at some time before the power rail **1** is expected to need to source more than 20 mA of current, for example, or as it "approaches" the 20 mA threshold.

[0071] Other manners and/or means of review of the power profile at reference numeral **208** are within the scope and spirit of the embodiments described herein. Generally, by relying upon the concepts for dynamic power mode switching per rail described above, power rails may be set to appropriate operating parameters based on actual real time power consumption rather than on semiconductor characterizations of expected consumption and processing state assumptions. Using accurate power measurements and statistics, the overall power management in battery-powered systems may be improved.

[0072] With regard to aspects of the structure or architecture of the system **10**, in various embodiments, each of the PMU controller **101**, the power processor **132**, and or other processors or processing circuits of the system **10** may comprise general purpose arithmetic processors, state machines, or Application Specific Integrated Circuits ("ASICs"), for example. Each such processor or processing circuit may be configured to execute one or more computer-readable software instruction modules. In certain embodiments, each processor or processing circuit may comprise a state machine or ASIC, and the processes described in FIGS. **5** and **6** may be implemented or executed by the state machine or ASIC according to the computer-readable instructions.

[0073] The memories and/or registers described herein may comprise any suitable memory devices that store computer-readable instructions to be executed by processors or processing circuits. These memories and/or registers store computer-readable instructions thereon that, when executed by the processors or processing circuits, direct the processors or processing circuits to execute various aspects of the embodiments described herein.

[0074] As a non-limiting example group, the memories and/or registers may include one or more of an optical disc, a magnetic disc, a semiconductor memory (i.e., a semiconductor, floating gate, or similar flash based memory), a magnetic tape memory, a removable memory, combinations thereof, or any other known memory means for storing computer-readable instructions.

[0075] In certain aspects, the processors or processing circuits are configured to retrieve computer-readable instructions and/or data stored on the memories and/or registers for execution. The processors or processing circuits are further configured to execute the computer-readable instructions to implement various aspects and features of the embodiments described herein.

[0076] Although embodiments have been described herein in detail, the descriptions are by way of example. The features of the embodiments described herein are representative and, in alternative embodiments, certain features and elements may be added or omitted. Additionally, modifications to aspects of the embodiments described herein may be made by those skilled in the art without departing from the spirit and scope of the present invention defined in the following claims, the scope of which are to be accorded the broadest interpretation so as to encompass modifications and equivalent structures.

1. A method, comprising:
sensing, with a current sense circuit in a system, an amount of current supplied by at least one of a plurality of power rails;
profiling the amount of current over a period of time; and
based on the profiling, maintaining a power profile of power consumed by at least one of a plurality of system elements in the system.

2. The method according to claim **1**, further comprising:
based on the power profile, identifying a system element as a source of heat in the system; and
changing an output voltage of or powering down a power rail associated with the system element.

3. The method according to claim **1**, further comprising identifying an unexpected ongoing processing status or state of an element in the system based on the amount of current.

4. The method according to claim **1**, further comprising:
comparing the amount of current to a threshold; and
when the amount of current is less than the threshold, setting at least one of the plurality of power rails into a low power mode of operation.

5. The method according to claim **1**, further comprising:
comparing the amount of current to a threshold; and
when the amount of current approaches the threshold, setting at least one of the plurality of power rails into a normal power mode of operation.

6. The method according to claim **1**, wherein:
sensing the amount of current comprises sensing an amount of current supplied by each of the plurality of power rails; and
profiling the amount of current comprises profiling the amount of current supplied by each of the plurality of power rails over the period of time.

7. The method according to claim **6**, further comprising, based on the profiling, maintaining a power profile for the plurality of system elements in the system

8. The method according to claim **6**, further comprising displaying the power profile as an amount of power consumed by the plurality of system elements over time.

9. The method according to claim **1**, wherein maintaining the power profile comprises maintaining the power profile based on the amount of current and a voltage of at least one of the plurality of system elements in the system.

10. A system, comprising:
a current sense circuit that senses an amount of current supplied by at least one of a plurality of power rails; and
a power manager circuit that:
evaluates the amount of current over a period of time; and
maintains a power profile of power consumed by at least one of a plurality of system elements in the system.

11. The system according to claim **10**, wherein the power manager circuit further:
identifies a system element as a source of heat in the system based on the power profile; and
changes an output voltage of or powers down a power rail associated with the system element.

12. The system according to claim **10**, wherein the power manager circuit further identifies an unexpected ongoing processing status or state of an element in the system based on the amount of current.

13. The system according to claim **10**, wherein the power manager circuit further:
compares the amount of current to a threshold; and
sets at least one of the plurality of power rails into a low power mode of operation when the amount of current is less than the threshold.

14. The system according to claim **10**, wherein the power manager circuit further:
compares the amount of current to a threshold; and
sets at least one of the plurality of power rails into a normal power mode of operation when the amount of current approaches the threshold.

15. The system according to claim **10**, wherein:
the current sense circuit senses an amount of current supplied by each of the plurality of power rails; and
the power manager circuit profiles the amount of current supplied by each of the plurality of power rails over the period of time.

16. A method, comprising:
sensing, with a current sense circuit in a system, an amount of power supplied by a plurality of power rails;
profiling the amount of power; and
based on the profiling, maintaining a power profile of power consumed by a plurality of system elements in the system.

17. The method according to claim **16**, further comprising:
based on the power profile, identifying a system element as a source of heat in the system; and
changing an output voltage of or powering down a power rail associated with the system element.

18. The method according to claim **16**, further comprising identifying an unexpected ongoing processing status or state of an element in the system based on the amount of power.

19. The method according to claim **16**, further comprising:
comparing the amount of power to a threshold;
when the amount of power is less than the threshold, setting at least one of the plurality of power rails into a low power mode of operation; and
when the amount of power approaches the threshold, setting at least one of the plurality of power rails into a normal power mode of operation.

20. The method according to claim **16**, wherein

sensing the amount of power comprises sensing an amount of current supplied by each of the plurality of power rails; and

profiling the amount of power comprises profiling the amount of current supplied by each of the plurality of power rails over the period of time.

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