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(54) **METHOD, SYSTEM, AND APPARATUS FOR VOLTAGE SENSING AND REPORTING**

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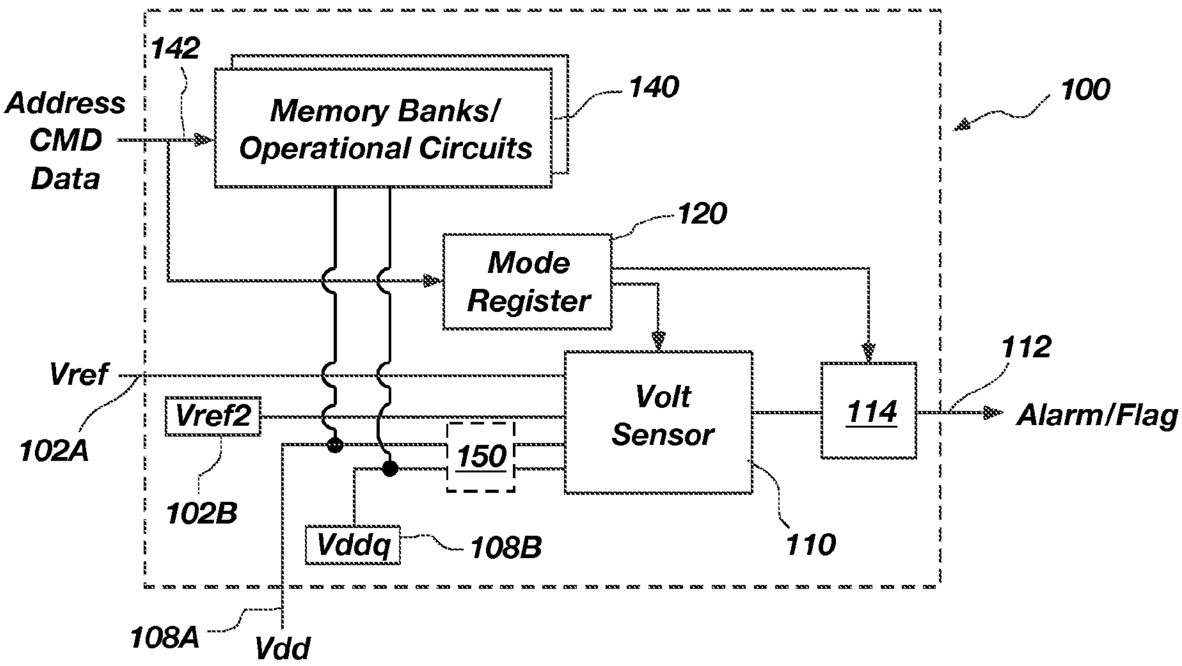
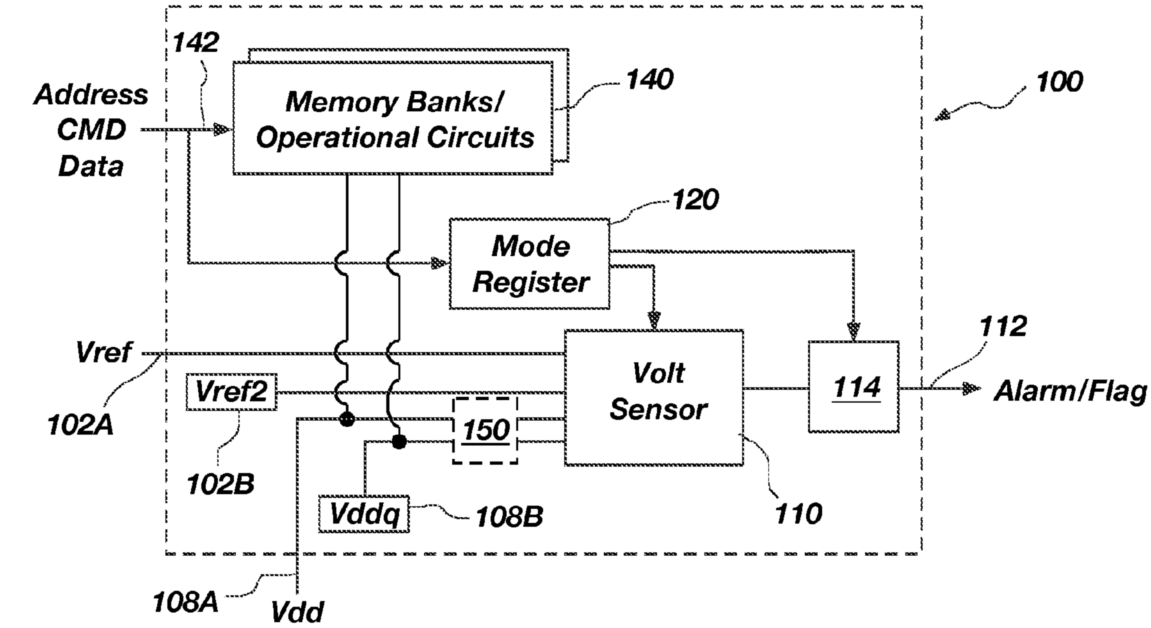
(57) **ABSTRACT**

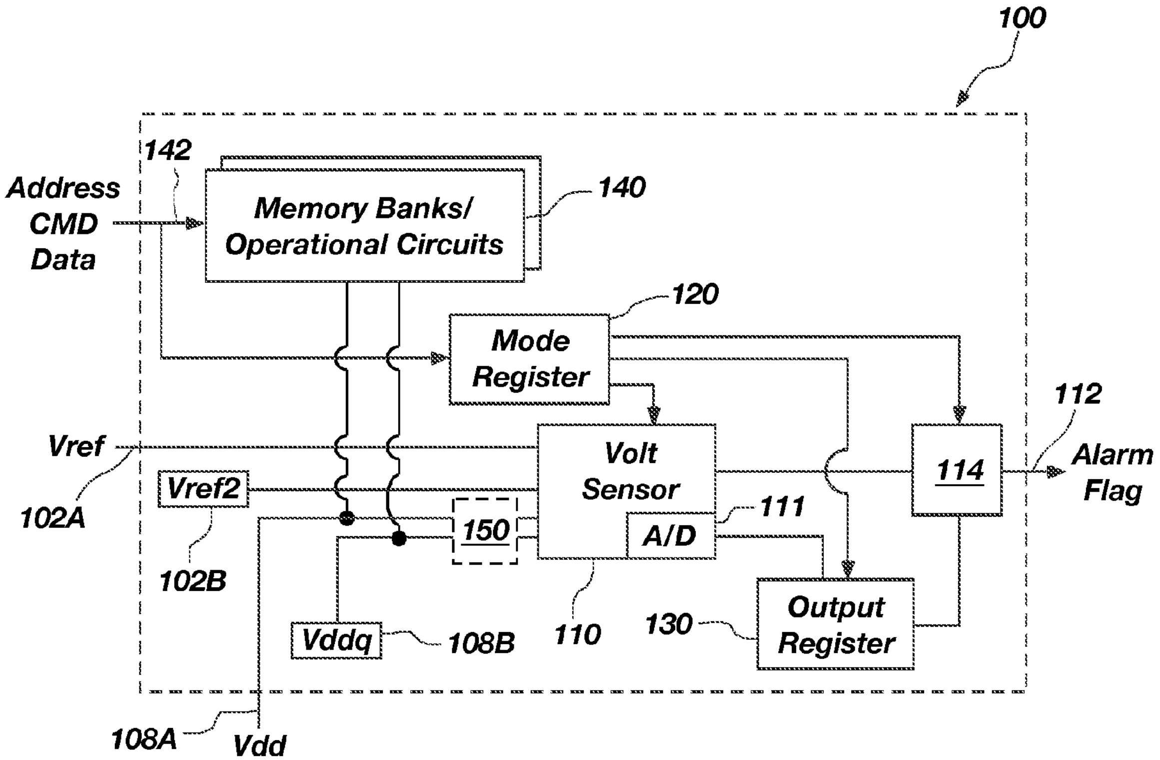
A method, apparatus and system are disclosed for sensing and reporting voltage levels in a semiconductor device. One such voltage sensor and reporting device is configured to sense and compare a reference voltage and an operating voltage. In one or more embodiments we voltage sensor is also configured to generate an alarm signal if the difference between the operating voltage and the reference voltage indicates the operating voltage is outside of a normal operating range.





142
Address
CMD
Data
Memory Banks/
Operational Circuits
140
100
120
Mode
Register
Vref
Volt
Sensor
114
112
Alarm/Flag
102A
Vref2
102B
150
Vddq
108B
110
108A
Vdd

FIG. 1



100
142
Address
CMD
Data
Memory Banks/
Operational Circuits
140
120
Mode
Register
112
Vref
Volt
Sensor
114
Alarm
Flag
102A
Vref2
111
150
A/D
102B
Vddq
108B
110
130
Output
Register
108A
Vdd

FIG. 2

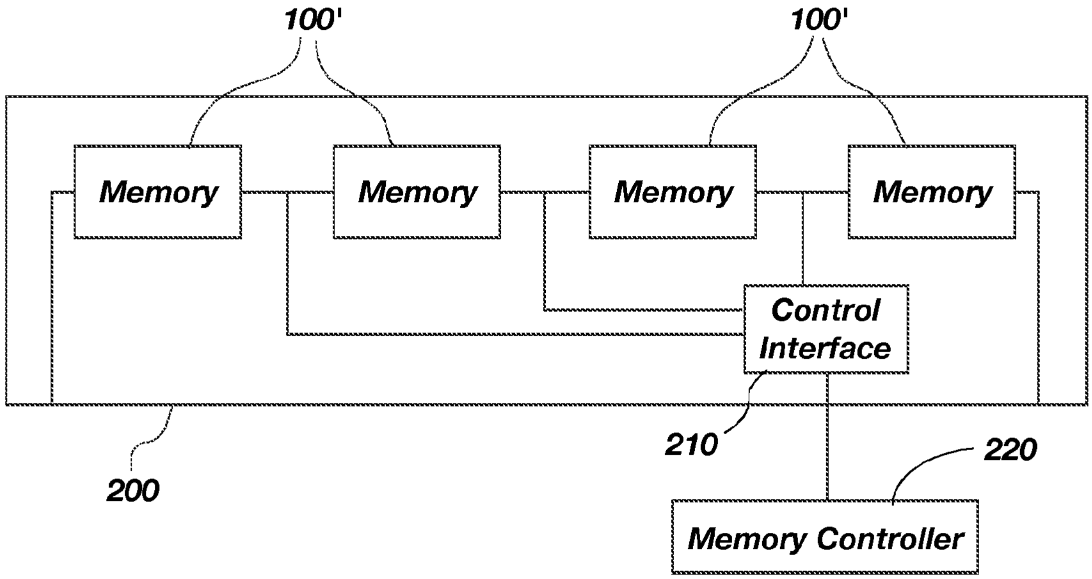

100'
100'
Memory
Memory
Memory
Memory
Control Interface
200
210
220
Memory Controller

FIG. 3

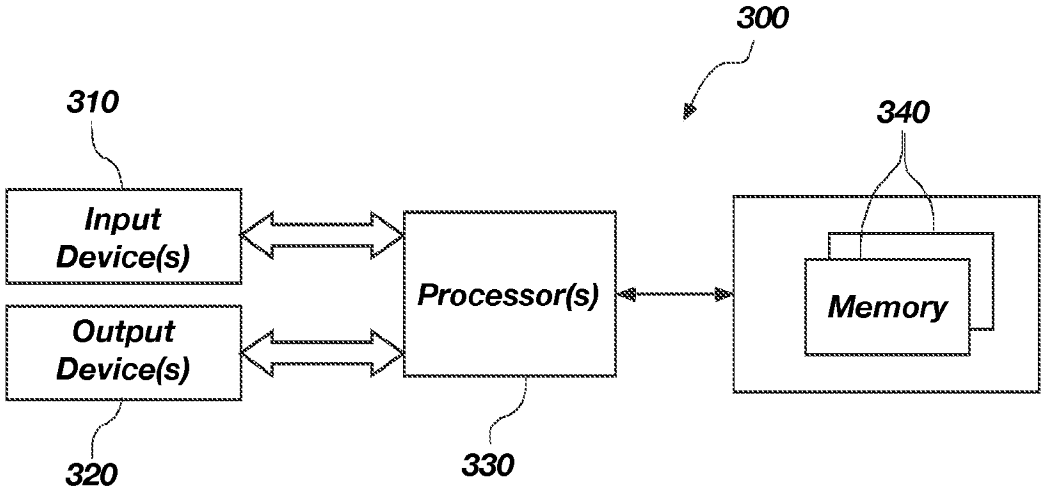

300
310
340
Input Device(s)
Processor(s)
Memory
Output Device(s)
320
330

FIG. 4

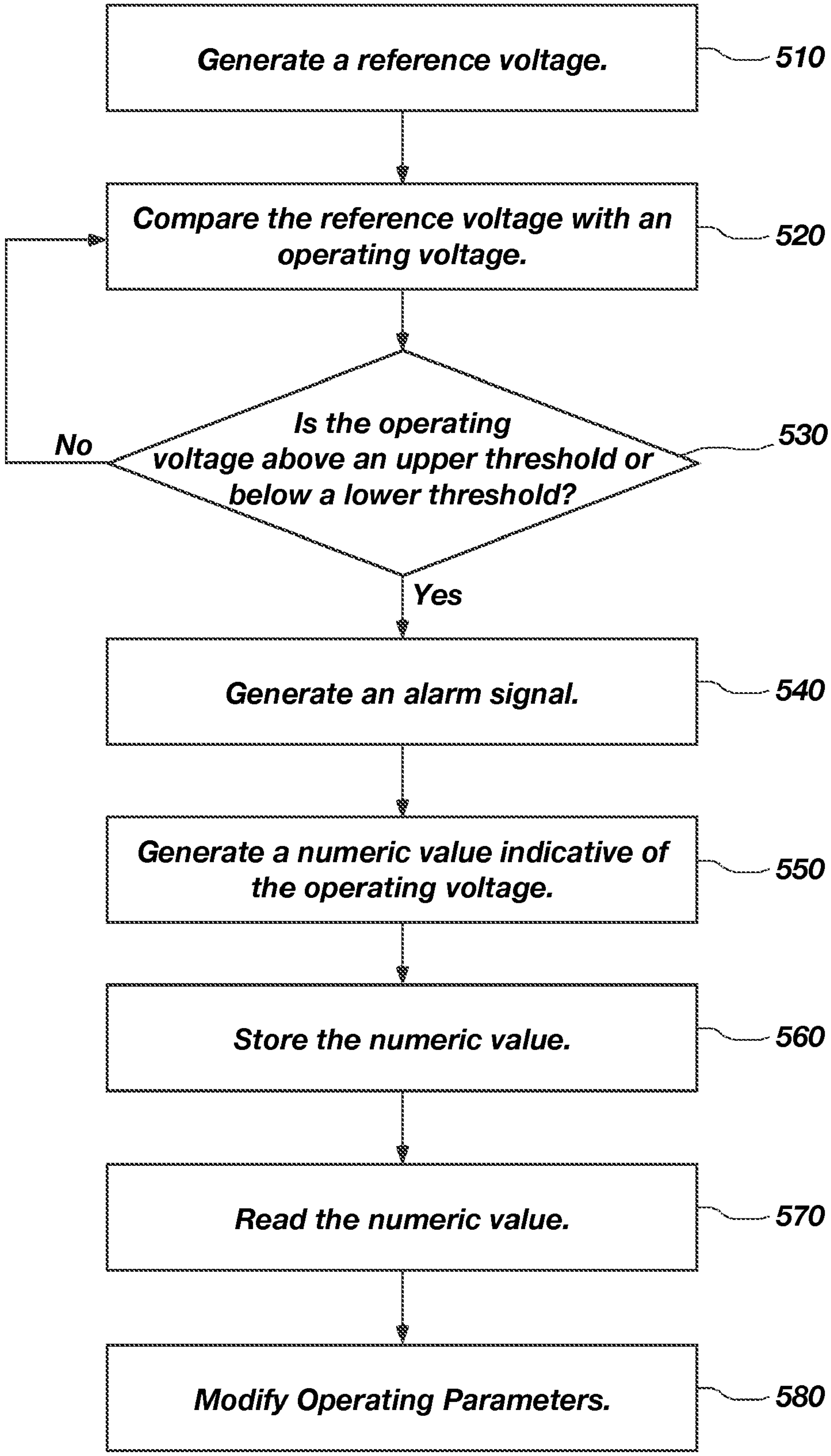

Generate a reference voltage.
510
Compare the reference voltage with an operating voltage.
520
Is the operating voltage above an upper threshold or below a lower threshold?
530
No
Yes
Generate an alarm signal.
540
Generate a numeric value indicative of the operating voltage.
550
Store the numeric value.
560
Read the numeric value.
570
Modify Operating Parameters.
580

FIG. 5

METHOD, SYSTEM, AND APPARATUS FOR VOLTAGE SENSING AND REPORTING

FIELD OF THE INVENTION

[0001] Embodiments of the present invention relate to voltage sensors and, particularly, in one or more embodiments, to determining and reporting various voltages on a semiconductor device, sensing and reporting methods, and systems including sensing and reporting capability.

BACKGROUND

[0002] Semiconductor devices, like most electronic products, are sensitive in their operation to supplied voltage levels. If voltage levels at working parts are lower than specified minimum requirements, the parts may malfunction. If voltage levels are higher than specified maximum requirements, the parts may malfunction and can also suffer catastrophic failure. In semiconductor memory devices, for example, such as Dynamic Random Access Memories (DRAMs), inadequate voltage levels may cause memory parts to malfunction by reading out or storing incorrect information. Such low voltage failures are often difficult to detect, and even when they are detected the resultant functional and data errors can seldom be recovered.

[0003] Often, the semiconductor device is still operational when the voltage levels become marginal causing the device to potentially fail in some aspect. For example, a memory device may not meet its full timing specifications at low voltages, resulting in a failure to read correct data. Even though the read data may be correct, the access time until correct data is available may be longer than designated by the device specification. Similarly, a low voltage level may result in the memory device's bit-cell capacitors not having enough time to fully change during a write cycle, even though they would work correctly if given additional time to complete the write cycle. In such a case, the bit-cells cannot be properly read and the data becomes corrupted.

[0004] There are many causes for unsuitable voltage levels to semiconductor devices, such as power supply errors and power distribution path effects. Power supply errors may result when the power supply is inadequate, misadjusted, or fails all together. Power distribution path effects influence voltage levels, for example through transient noise signals, inductance, and/or resistance in power distribution paths. As semiconductor device activity increases, these power distribution path effects often add together and further increase the chances of data and functional errors.

[0005] Historically, voltage sensors have been used to detect the voltage levels coming directly from the power supplies. However, these devices are limited to sensing voltage errors in he supply voltage. These systems are not capable of detecting whether voltage levels are unsuitable at specific locations (e.g., circuits) within the semiconductor device itself. Thus, these devices do not detect unsuitable voltage levels not caused by the voltage source itself, such as the distribution path effects described above.

[0006] In view of the shortcomings in the prior art, it would be advantageous to provide a semiconductor device capable of sensing and/or reporting voltage levels at operational circuits within the semiconductor device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** is a block diagram illustrating a semiconduc-

[0008] FIG. **2** illustrates a voltage sensing and reporting device including numeric result reporting according to one embodiment of the invention.

[0009] FIG. **3** is a memory card containing a plurality of semiconductor memory devices containing a voltage sensing and reporting device according to one embodiment of the invention.

[0010] FIG. **4** is a computing system diagram showing a plurality of semiconductor memories containing a voltage sensing and reporting device according to one embodiment of the invention.

[0011] FIG. **5** is a flow diagram illustrating a method for sensing and reporting voltage in a semiconductor memory device according to one embodiment of the invention.

DETAILED DESCRIPTION

[0012] In the following detailed description, circuits and functions may be shown in block diagram form in order not to obscure the present invention in unnecessary detail. Additionally, block definitions and partitioning of logic between various blocks as depicted is non-limiting, and comprise examples of only specific implementations. It will be readily apparent to one of ordinary skill in the art that the present invention may be practiced in a variety of embodiments implementing numerous other partitioning solutions.

[0013] Also, it is noted that the embodiments may be described in terms of a process that is depicted as a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe operational acts as a sequential process, many of these acts can be performed in another sequence, in parallel, or substantially concurrently. In addition, the order of the acts may be re-arranged. A process is terminated when its acts are completed. A process may correspond to a method, a function, a procedure, a subroutine, a subprogram, etc. When a process corresponds to a function, its termination corresponds to a return of the function to the calling function or the main functions

[0014] FIG. **1** is a block diagram illustrating a semiconductor memory device **100** including a voltage sensing and reporting device according to one embodiment. The semiconductor memory device **100** may be a DRAM with conventional memory banks and operational circuits **140** and be controlled by conventional address, command, and data buses **142**. Semiconductor memory device **110** includes at least one voltage sensor **110** for sensing voltages. The at least one voltage sensor **110** may include a voltage comparator configured according to any of the known configurations in the art. The voltage comparator may be configured to compare an operating voltage (**108**A, **108**B), such as V_{dd} or V_{ddq}, to a reference voltage (**102**A, **102**B), such as V_{ref} or V_{ref2}, for determining a voltage difference. The term "voltage difference," as used herein, refers to a quantifiable difference between the operating voltage level and the reference voltage level, which difference may be expressed as a numerical value.

[0015] The operating voltage (**108**A, **108**B) may be a supply voltage **108**A from an input pin or may be an operating voltage **108**B generated internally on the semiconductor memory device **100**. The operating voltage (**108**A, **108**B) may be configured to supply a voltage to one or more operational circuits **140** of the semiconductor memory device **100**. By way of example and not limitation, operational circuits

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