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(54) **THERMAL SENSING METHOD AND SYSTEM**

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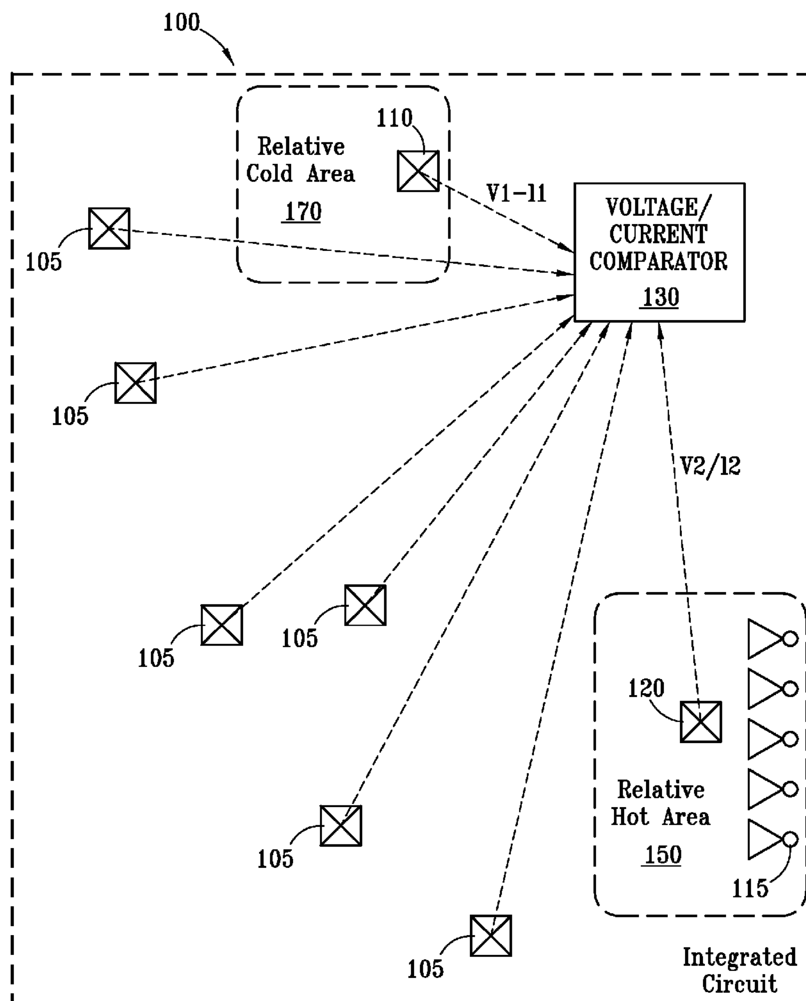
(57) **ABSTRACT**

The present invention provides a method for determining a hot area of an integrated circuit. A first temperature sensor in a first area of a chip is read, the chip comprising a plurality of chip areas, wherein the first area is a comparison area. The comparison area comprises at least one I/O device that is controlled to simulate other functional I/O devices on the chip. A second temperature sensor in a second area of a chip is read. The readings of the first temperature sensor and the second temperature sensor are compared. If the difference between the first temperature reading and the second temperature reading exceeds a threshold, a first error condition is indicated.



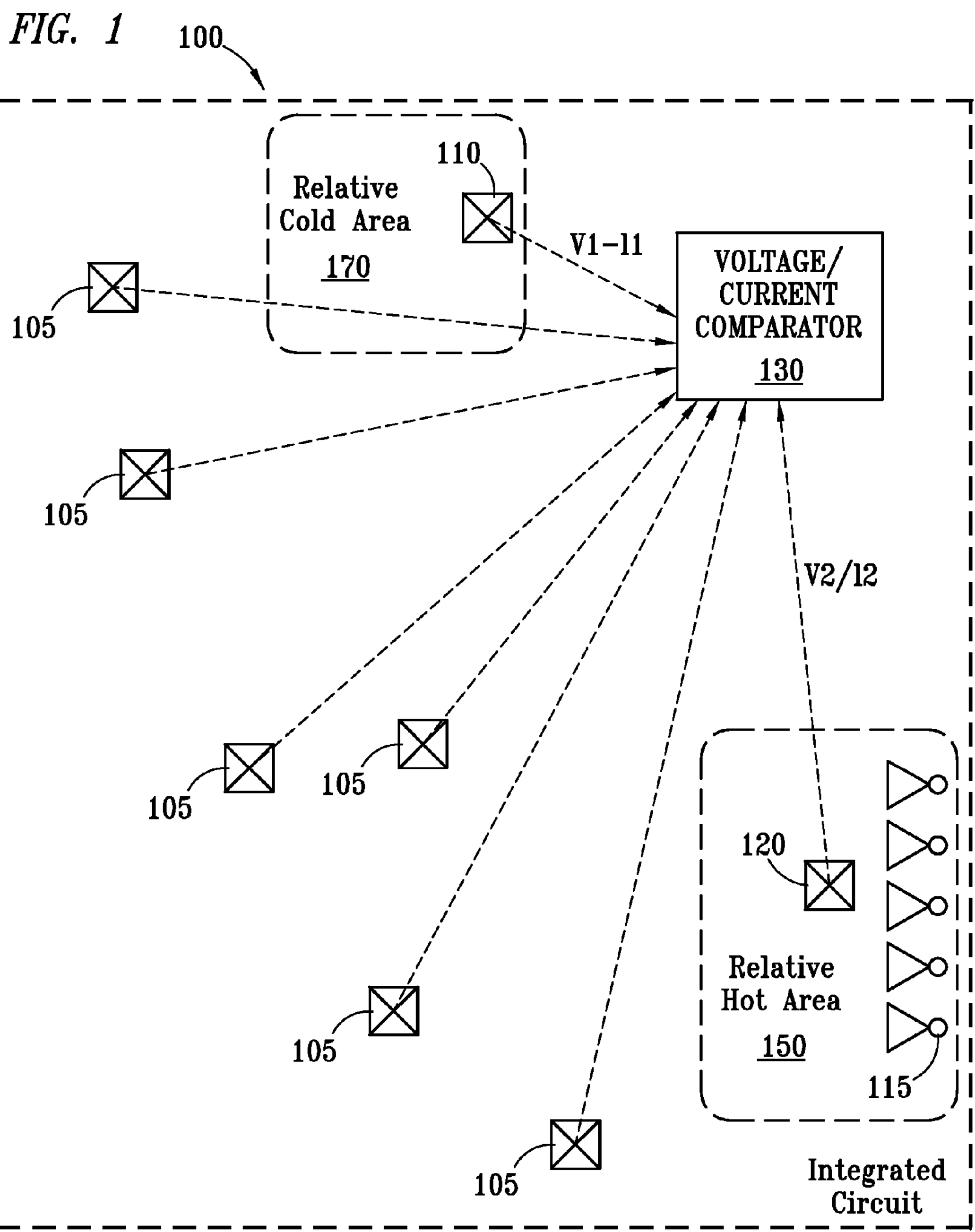


FIG. 1
100
Relative
Cold Area
170
110
V1-I1
VOLTAGE/
CURRENT
COMPARATOR
130
105
105
105
105
V2/I2
120
Relative
Hot Area
150
115
105
105
Integrated
Circuit

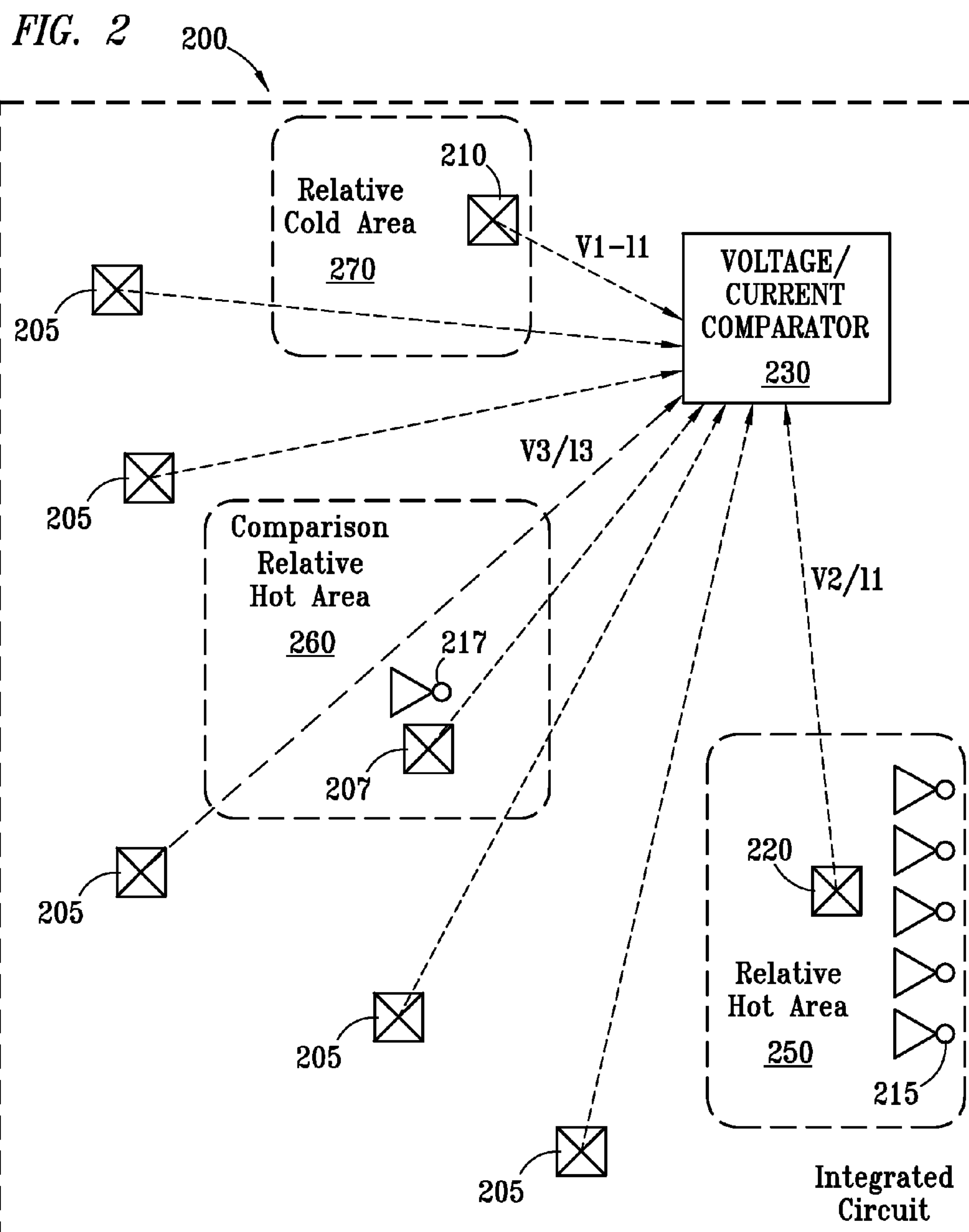


FIG. 2
200
Relative
Cold Area
270
210
V1-I1
VOLTAGE/
CURRENT
COMPARATOR
230
205
205
V3/I3
Comparison
Relative
Hot Area
260
217
207
V2/I1
205
220
Relative
Hot Area
250
205
215
205
Integrated
Circuit

THERMAL SENSING METHOD AND SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a division of, and claims the benefit of the filing date of, co-pending U.S. patent application Ser. No. 10/606,586 entitled THERMAL SENSING METHOD AND SYSTEM, filed Jun. 26,2003.

TECHNICAL FIELD

[0002] The invention relates generally to thermal sensing and, more particularly, to thermal sensing in an integrated circuit.

BACKGROUND

[0003] A complementary metal-oxide semiconductor (CMOS) is one type of transistor used in an integrated circuit (IC). CMOS transistors generate heat when switching from an off state to an on state, or from an on state to an off state, within the IC. If this heat is neither properly dissipated nor otherwise accounted or compensated for, the CMOS transistor can experience degradation leading to CMOS transistor failure.

[0004] Silicon on insulator (SOI) technology can be employed in CMOS fabrication. Generally, SOI is a manufacturing technique in which devices are fabricated on top of a relatively thick layer of silicon dioxide ($Si0_2$), thereby reducing the capacitances of the individual CMOS transistors. The reduction of capacitances of the CMOS transistors can result in significant processing gains in terms of speed of processing.

[0005] However, although the IC can have an associated temperature sensor, there can be significant variation in the readings obtained from the temperature sensor from IC to IC. Therefore, a calibration of the temperature sensor is performed to compensate for this variation. Calibration of temperature sensors can be time intensive and costly. Furthermore, the measurement of heat by the temperature sensors in ICs, such as an IC manufactured using the silicon on insulator (SOI) approach, has proven problematic, due to such factors as thermal isolation of CMOS transistors in the chip.

[0006] Therefore, what is needed is an IC chip and method that measures temperature that solves at least some of the disadvantages of conventional ICs that measure temperature.

SUMMARY OF THE INVENTION

[0007] The present invention provides a method for determining a hot area of an integrated circuit. A first temperature sensor in a first area of a chip is read, the chip comprising a plurality of chip areas, wherein the first area is a comparison area. The comparison area comprises at least one I/O device that is controlled to simulate other functional I/O devices on the chip. A second temperature sensor in a second area of a chip is read. The readings of the first temperature sensor and the second temperature sensor are compared. If the difference between the first temperature reading and the second temperature reading exceeds a threshold, a first error condition is indicated.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following Detailed Description taken in conjunction with the accompanying drawings, in which:

[0009] FIG. **1** schematically depicts an IC having a plurality of temperature sensors distributed in a plurality of areas of the IC; and

[0010] FIG. **2** schematically depicts an IC chip having a plurality of temperature sensors distributed in a plurality of areas of the IC, and a third sensor is a simulated "hot spot" area of the IC.

DETAILED DESCRIPTION

[0011] In the following discussion, numerous specific details are set forth to provide a thorough understanding of the present invention. However, those skilled in the art will appreciate that the present invention may be practiced without such specific details. In other instances, well-known elements have been illustrated in schematic or block diagram form in order not to obscure the present invention in unnecessary detail. Additionally, for the most part, details concerning network communications, electromagnetic signaling techniques, and the like, have been omitted inasmuch as such details are not considered necessary to obtain a complete understanding of the present invention, and are considered to be within the understanding of persons of ordinary skill in the relevant art.

[0012] It is further noted that, unless indicated otherwise, all functions described herein may be performed in either hardware or software, or some combination thereof In a preferred embodiment, however, the functions are performed by a processor, such as a computer or an electronic data processor, in accordance with code, such as computer program code, software, and/or integrated circuits that are coded to perform such functions, unless indicated otherwise.

[0013] Turning to FIG. **1**, disclosed is an IC **100**. The IC **100** has a plurality of temperature sensors **105**. Each temperature sensor **105** is coupled to or embedded within its own area of the IC **100**. The IC **100** further has a relative hot area **150** and a relative cold area **170**. Generally, the heat generated in the areas **150** and **170** can be proportional to the use of devices within that area, and the type of devices in those areas. For instance, in FIG. **1**, the hot area **150** has a plurality of input/output (IO) devices **115**. In one embodiment, the IO devices **115** are used more extensively than devices in the cold area **170**. Therefore, more heat is generated in the hot area **150**.

[0014] The IC **100** comprises the first temperature sensor **110** in the cold area **170** and the second temperature sensor **120** in the hot area **150**. Generally, the temperature sensors **105**, **110** and **120** generate a voltage that is proportional to the measured temperature. The first temperature sensor **110** generates a voltage V**1**, and the second temperature sensor generates a voltage V**2**. The temperature sensors **105** can be manufactured with pn junctions, thermal resistors, a voltage producing metal, a well implant, and so on. However, in another embodiment, the temperature sensors **105**, **110** and **120** generate a current that is proportional to the measured temperature.

[0015] These voltages are input into a voltage comparator **130**. Alternatively, these currents are input into a current comparator **130**. Although not illustrated for ease of description, the temperature sensors **105** also generate their own voltages or currents as a function of temperature, and these voltages are also input into the voltage comparator **130** for differential temperature comparison.

[0016] The voltage comparator **130** determines the difference between the various voltages V**1**, V**2** and so on. If the difference is below a given threshold, the corresponding temperature difference between the hot area **150** and the cold area **170**, or other voltage comparisons of interest, does not indicate an error condition. However, if the voltage difference is above a given threshold, an error condition is indicated in an indicator signal generated by the voltage comparator **130**. The current comparator **130** can determine the difference between the various currents output by the sensors, and employ this difference in a similar manner to the difference measured by the voltage comparator **130**.

[0017] "Relative" temperatures are employed in determining if an error condition in the IC **100** is indicated. Relative temperatures can generally be defined as the difference in temperature from one area of the IC **100** compared to another area of the IC **100**. Relative temperature sensing can reduce or eliminate some process variation problems from temperature sensor to temperature sensor. The relative sensitivity of temperature sensors within the same IC typically vary less than the relative sensitivity of temperature sensors between two separate ICs. Therefore, employing a plurality of temperature sensors in the same IC **100**, one temperature sensor measured to another temperature sensor, can be less manufacturing process intensive than calibrating each temperature sensor to a standard temperature.

[0018] In one embodiment, an absolute temperature sensor for the chip is not employed to determine an error condition. In other words, the relative temperature differences, as measured by the temperature sensors **105**, **110**, and **120** and compared by the voltage comparator **130** are employed to determine error conditions within the IC **100**. However, no temperature that is not compared to another temperature is employed by the voltage comparator **130**.

[0019] Relative temperature differences between the hot area **150** and the cold area **170** are determined by the voltage comparator **130**. A relative temperature difference that exceeds a certain threshold can indicate an error condition. The occurrence of hot areas and cold areas in an IC can be especially pronounced in SOI ICs, due to the high thermal resistance of the buried oxide. In an SOI circuit, there can be substantial thermal isolation between devices in close proximity to one another. Therefore, relative "hot spots" in the IC chip can develop due to the uneven utilization of CMOS and other devices distributed throughout the IC. The hot spot or hot spots are monitored by one or more temperature sensors **120** and compared with the temperature measured by temperature sensors **110** to determine if an error is indicated.

[0020] In a further embodiment, the temperature sensors **105** have differing temperature versus voltage or current characteristics. For instance, the voltage or current generated at a given temperature can differ from one temperature sensor **105** to another temperature sensor **105**, the increase in voltage generated for a given increase in temperature can differ, and so on. The voltage comparator **130** is employable to compensate for the various temperature to voltage conversion of the temperature sensors **105**, and to employ the compensated readings to determine whether the voltage differential exceeds a threshold.

[0021] Turning now to FIG. **2**, disclosed is an IC **200**. The IC **200** has a plurality of temperature sensors **205**. Each temperature sensor **205** is coupled to or embedded within its own area of the IC **200**. The IC **200** further has a relative hot area **250** and a relative cold area **270**. The IC **200** still further has a comparison relative hot area **260**. The comparison relative hot area **260** comprises a comparison I/O device **217** and a temperature sensor **207**. Generally, the comparison I/O device **217** simulates the activity of I/O devices **215**, thereby generating comparable heat characteristics.

[0022] The IC **200** further comprises a first temperature sensor **210** in the cold area **270**, a second temperature sensor **220** in the hot area **250** and a third temperature sensor **207** in the hot comparison area **260**. The first temperature sensor **210** generates a voltage V**1**, the second temperature sensor generates a voltage V**2**, and the third temperature sensor **207** generates a voltage V**3**. These voltages are input into a voltage comparator **230**. Alternatively, the first temperature sensor **210** generates a first current I**1**, the second temperature sensor generates a second current I**2**, and the third temperature sensor **207** generates a third current I**3**. These are input into a current comparator **230**.

[0023] The voltage comparator **230** determines the difference between the various voltages V**1** and V**2**. Similarly, the current comparator **230** determines the difference between the first and second current. If the difference is below a given threshold, the corresponding temperature difference between the hot area **250** and the cold area **270** does not indicate an error condition. However, if the difference is above a given threshold, an error condition is indicated in an indicator signal.

[0024] Furthermore, the voltage comparator **230** compares the difference between the voltages V**2** and V**3** or the current comparator **230** compares the difference between the second current and the third current. Because the comparison relative hot area **260** has a similar temperature as the relative hot area **250**, the measurements generated by the temperature sensors **207** and **220** are similar. However, if the temperature sensors **207** and **220** diverge in their measurements as determined by the voltage comparator **230**, an error condition is indicated. The error condition can be a faulty temperature sensor **207**, **220**. The error can also be in the I/O circuits **215**. In any event, the voltage or current comparator **230** can generate a "too hot" or "too cold" signal, which can be employed by some other part of the IC chip or the operating system running in the IC chip.

[0025] It is understood that the present invention can take many forms and embodiments. Accordingly, several variations may be made in the foregoing without departing from the spirit or the scope of the invention. The capabilities outlined herein allow for the possibility of a variety of programming models. This disclosure should not be read as preferring any particular programming model, but is instead directed to the underlying mechanisms on which these programming models can be built.

[0026] Having thus described the present invention by reference to certain of its preferred embodiments, it is noted

that the embodiments disclosed are illustrative rather than limiting in nature and that a wide range of variations, modifications, changes, and substitutions are contemplated in the foregoing disclosure and, in some instances, some features of the present invention may be employed without a corresponding use of the other features. Many such variations and modifications may be considered obvious and desirable by those skilled in the art based upon a review of the foregoing description of preferred embodiments. Accordingly, it is appropriate that the appended claims be construed broadly and in a manner consistent with the scope of the invention.

1. A method for determining a hot area of an integrated circuit, comprising:

reading a first temperature sensor in a first area of a chip, the chip comprising a plurality of chip areas, wherein the first area is a comparison area;

wherein the comparison area comprises at least one I/O device that is controlled to simulate other functional I/O devices on the chip;

reading a second temperature sensor in a second area of a chip;

comparing the readings of the first temperature sensor and the second temperature sensor; and

if the difference between the first temperature reading and the second temperature reading exceeds a threshold, indicating a first error condition.

2. The method of claim 1, wherein the first temperature sensor measures a temperature to generate a current and reading a first temperature sensor comprises detecting the current.

3. The method of claim 1, wherein the first temperature sensor measures a temperature to generate a voltage and reading a first temperature sensor comprises detecting the voltage.

4. The method of claim 1, wherein the temperature sensor comprises a pn junction.

5. The method of claim 1, wherein the temperature sensor comprises a thermal resistor.

6. The method of claim 1, further comprising:

reading a third temperature sensor in a third area of the chip;

comparing the readings of the first temperature sensor and the second temperature sensor, to generate a first comparison value;

comparing the readings of the first temperature sensor and the third temperature sensor, to generate a second comparison value; and

if the difference between the first comparison value and the second comparison value exceeds a threshold, indicating an second error condition.

7. The method of claim 1, further comprising:

selecting the first area of the chip wherein the first temperature sensor is distributed to a relative cold part of the chip; and

selecting the second area of the chip wherein the second temperature sensor is distributed to a relative hot part of the chip.

8. The method of claim 6, further comprising:

selecting the first area of the chip wherein the first temperature sensor is distributed to a relative cold part of the chip;

selecting the second area of the chip wherein the second temperature sensor is distributed to a relative hot part of the chip; and

selecting the third area of the chip wherein the third temperature sensor is distributed to a relative hot part of the chip.

9. A processor for determining a hot area of an integrated circuit, the processor including a computer program product comprising a computer-readable medium with a computer program embodied thereon, the computer program comprising:

computer code for reading a first temperature sensor in a first area of a chip, the chip comprising a plurality of chip areas, wherein the first area is a comparison area;

wherein the comparison area comprises at least one I/O device that is controlled to simulate other functional I/O devices on the chip;

computer code for reading a second temperature sensor in a second area of a chip;

computer code for comparing the readings of the first temperature sensor and the second temperature sensor; and

computer code for, if the difference between the first temperature reading and the second temperature reading exceeds a threshold, indicating a first error condition.

10. The processor of claim 9, wherein the first temperature sensor measures a temperature to generate a current and computer code for reading a first temperature sensor comprises computer code for detecting the current.

11. The processor of claim 9, wherein the first temperature sensor measures a temperature to generate a voltage and computer code for reading a first temperature sensor comprises computer code for detecting the voltage.

12. The processor of claim 9, wherein the temperature sensor comprises a pn junction.

13. The processor of claim 9, wherein the temperature sensor comprises a thermal resistor.

14. The processor of claim 9, further comprising:

computer code for reading a third temperature sensor in a third area of the chip;

computer code for comparing the readings of the first temperature sensor and the second temperature sensor, to generate a first comparison value;

computer code for comparing the readings of the first temperature sensor and the third temperature sensor, to generate a second comparison value; and

computer code for, if the difference between the first comparison value and the second comparison value

exceeds a threshold, indicating an second error condition.

15. The processor of claim 9, further comprising:

computer code for selecting the first area of the chip wherein the first temperature sensor is distributed to a relative cold part of the chip; and

computer code for selecting the second area of the chip wherein the second temperature sensor is distributed to a relative hot part of the chip.

16. The processor of claim 14, further comprising:

computer code for selecting the first area of the chip wherein the first temperature sensor is distributed to a relative cold part of the chip;

computer code for selecting the second area of the chip wherein the second temperature sensor is distributed to a relative hot part of the chip; and

computer code for selecting the third area of the chip wherein the third temperature sensor is distributed to a relative hot part of the chip.

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