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(54) **Title**: SYSTEM AND METHOD FOR CONTROLLING INTERNAL TEMPERATURE OF ELECTRONIC COMPONENTS

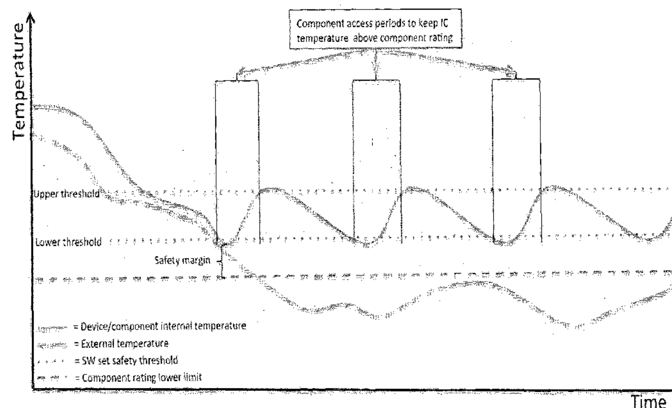

FIG.1

(57) **Abstract**: Methods and related apparatus for controlling internal temperature of electronic components, and maintaining the temperature within an operating range in automotive applications are described. The method includes an individual activity based temperature compensation scheme where current state of components is determined, determining a lower threshold, initiating a heating routine, monitoring the temperature of components, and determining whether, the temperature of the components reaches a threshold, and ending the heating routine.

SYSTEM AND METHOD FOR CONTROLLING INTERNAL TEMPERATURE OF ELECTRONIC COMPONENTS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of Indian provisional patent application 814/DEL/2012 filed March 20, 2012, which is incorporated by reference as if fully set forth herein.

FIELD OF INVENTION

[0002] The invention generally relates to a system and a method for controlling and maintaining the internal temperature of the electronic components within an operating temperature range in automobiles.

BACKGROUND

[0003] Integrated circuit (IC) transistors, and components, such as application specific integrated circuits (ASICs), memories, etc. are designed to work at the optimum operating temperature for their lifetime, usually about 10 years. This operating temperature varies with the type of ICs that are manufactured in several grades depending upon operating environment. For example, commercial grade with operating temperature in the range of 0 ° Centigrade (C) to 70 °C (sometimes -10 °C to 70 °C); industrial grade with operating temperature in the range of -25 °C to 85 °C (sometimes -40 °C to 85 °C); and military grade with operating temperature in the range of -55 °C to 125 °C (sometimes -65 °C to 175 °C).

[0004] The life of the component as well as its efficiency is dependent upon the consistent working of the component within the operating temperature range. IC operation at temperatures lower than the operating temperature for a particular grade component, results in decreased lifetime and efficiency of the component.

[0005] At temperatures beyond the operating temperature range, the logic behavior of the IC may be not verified and output of the IC may become unpredictable

(metastable) and component starts failing. This problem, to an extent has been overcome by manufacturing the components that are designed, and characterized for working at wider temperature ranges such as in automotive and military grade components. For example, automotive grade devices have wider operational temperature range (- 40 °C to 85 °C). However, such wider operational temperature range components are expensive and are not viable for all commercial, and / or industrial purposes. In particular, memory technologies with reasonable cost have limitation at lower end of temperature range and therefore their operational temperature range is limited to a minimum of -20°C.

[0006] Another option to control the logic behavior of components beyond their operating temperature range is to provide an external aid. This external aid, usually in the form of additional components, to externally heat (or cool) the required component to keep them within their operating range. One such example is use of heat sinks. These heat sinks are available in sizes as small as 0.25" x 0.25" (6.4 mm x 6.4 mm) to fit electronic components which includes temperature stabilization of crystal oscillators, thermal stress testing of integrated circuits, and simulation of heat-emitting components to evaluate performance of cooling systems. Such additional/external means of heating, however, not only add up to the total cost of functioning of the component, but are also complex and create architectural impediments in the device. Thus it is desirable to have electronic components that are not only cost-effective but also work in a wider temperature range equivalent to the operating temperature range of automotive / military grade component without any extra external aid.

SUMMARY

[0007] Accordingly, it is a general object of the invention to provide a system and a method of controlling and maintaining the internal temperature of electronic components of a device which is cost effective, yet operates at wider operating temperatures.

[0008] Another object of the invention is to provide a system and related method for controlling and maintaining the internal temperature of the electronic components of a device within the operating temperature range of the electronic components for maximum period of time to enhance the life, efficacy, stability and predictability of the device.

[0009]Yet another object of the invention is to provide a system, and method for controlling maintaining the internal temperature of the electronic components of a device within the operating temperature range of the electronic components at a wider range of external temperature, without employing high grade electronic components or any external means of heating / cooling.

[0010] Another object of the invention is to provide a system, and method for controlling and maintaining the internal temperature of the electronic components of a device within the operating temperature range of the electronic components, for a wider range of external temperature, which is cost-effective and simple in design.

[0011] Other objects, features, and advantage of the present invention will become apparent from the following detailed description.

BRIEF DESCRIPTION OF DRAWINGS

[0012]A more detailed understanding may be had from the following description, given by way of example in conjunction with the accompanying drawings wherein:

[0013]FIG. 1 illustrates a temperature compensation scheme depicting internal temperature and external temperature over time. Also temperature compensation access periods are indicated as well as components absolute rating limit and upper / lower threshold to activate temperature compensations scheme; and

[0014] FIG. 2 is a flow diagram of the working of the temperature compensation scheme of FIG.1;

DETAILED DESCRIPTION

[0015] It will be readily understood that the components of the present invention, as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations. Thus, the following detailed

description of the embodiments of a method and apparatus, as represented in the attached figures, is not intended to limit the scope of the invention as claimed, but is merely representative of selected embodiments of the invention.

[0016] The features, structures, or characteristics of the invention described throughout this specification may be combined in any suitable manner in one or more embodiments. For example, the usage of the phrases "certain embodiments," "some embodiments," or other similar language, throughout this specification refers to the fact that a particular feature, structure, or characteristic described in connection with the embodiment may be included in at least one embodiment of the present invention. Thus, appearances of the phrases "in certain embodiments," "in some embodiments," "in other embodiments," or other similar language, throughout this specification do not necessarily all refer to the same group of embodiments, and the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0017] Furthermore, as is consistent with the knowledge of one of ordinary skill in the art of electronics, a controller is defined as a chip or integrated circuit (IC) that interfaces with a peripheral device. Thus, as one of ordinary skill in the art would readily appreciate, the terms "controller" and "control IC" are interchangeable and refer to the same structure.

[0018] The described embodiments pertain to controlling and maintaining the internal temperature of various electronic components within their operating temperature range by use of temperature compensation mechanisms applied to a plurality of electronic components in a device without any external heating aid or use of higher grade components. The described embodiments also provide means of controlling internal temperature of electronic components.

[0019] In one embodiment, a system and method for controlling and maintaining the internal temperature of the electronic components of a device within the operating temperature range. In accordance with one embodiment, activity based temperature compensation among a plurality of electronic components is used to maintain the temperature of individual components within their operating temperature range

and thereby synchronizing the operating range of temperature of individual components to have a wider operating range of temperature for the device. By use of the described embodiments, an activity based compensation scheme is used to make distinct components within a device, work consistently within their operating temperature range even when the external temperature goes below the minimum / or alternately goes above the maximum.

[0020] In accordance with one embodiment, a temperature of the electronic component is sensed by an on-board integrated circuit (IC) or an embedded temperature sensor, and when temperature is found to be within a predetermined range or at a threshold – at a lower threshold limit, which limit could be pre-adjusted as component absolute rating limit plus a safety margin, of the electronic component, the other component / device that has even lower operation point diverts more activity on the first electronic component in the manner to ensures that the temperature of higher temperature devices will be kept above the minimum temperature limit.

[0021] In accordance with another embodiment, component level activity is increased by memory write/read operations, processor dummy operations and / or cellular device base station check routines / sub routines. In this embodiment, no separate heating element is required during heating as heating up takes place automatically while component(s) inside the device are activated. This practically allows the use of wider variety of electronic components in automotive devices wherein increased activity based heating is used when temperature goes below the optimum operating range. For example, memory technologies have limitations on lower temperatures and, eMMC type memories (an embedded non-volatile memory system, including both flash memory and a flash memory controller, usually integrated on the same silicon die), cannot be used below -20°C. This also allows electronic components made of cheaper Bill of Materials (BOM) such as non-automotive graded components to work in the operating temperature range of automotive grade devices.

[0022] In accordance with another embodiment of the present invention, the temperature compensation access scheme reflecting the device/component internal temperature and external temperature over time is illustrated in FIG. 1. FIG. 1 depicts the temperature compensation access periods as well as the components absolute rating limit and upper / lower threshold to activate temperature compensation scheme. In FIG. 1, the temperature of a component is sensed by an on-board or IC embedded temperature sensor, and when temperature is at a lower threshold limit of the electronic component the device that has even lower operation point puts more activity on electronic device in the manner that higher temperature devices temperature will be kept above minimum temperature limit. The lower threshold limit is the component specific absolute rating limit, and a safety margin.

[0023] Figure1 illustrates temperature compensation access scheme showing device internal temperature and external temperature over time. Also temperature compensation access periods are indicated as well as components absolute rating limit and upper/lower threshold to activate temperature compensations scheme.

[0024] In this manner, a lower temperature range than automotive graded parts can be used inside automotive graded device when temperature compensation is applied.

[0025] Also, separate heating elements are not used as the desired heat is generated at appropriate time by adding operational activity on the particular component/device. Since the low cost non-automotive parts can be used for automotive devices, it is highly cost-effective. Also, there is no additional cost or complexity involved in the structure as there are no external heating devices employed.

[0026] FIG. 2 illustrates a flow diagram of the implementing the described embodiments. A sensor determines where a particular component is in an idle state. Once the sensor determines that the component is not in an idle state, it then determines whether the temperature of the component is below a certain prescribed threshold. This threshold is usually a lower threshold (Th_l), and is either preconfigured in the sensor or the component itself or on a memory. Once the

sensor determines that the temperature of the component is below the Th_l, the sensor triggers a set of instructions to start a heating routine. This heating routine is configured to control access to peripheral systems including the described heating system. In addition, the heating routine is in a control feedback loop with battery components to monitor currently active and inactive components.

[0027] The sensor monitors the temperature of the component (either continuously or in a predetermined interval) and once the temperature reaches an upper threshold (Th_u) or within a prescribed range of the (Th_u), the sensor triggers a set of instructions to end the heating routine.

[0028] The sensor system may be included as part of an on-board system or as a standalone integrated circuit, or an Application Specific Integrated Circuit ("ASIC"), or the sensor system may be included separately as a Field Programmable Gate Array (FPGA).

[0029] In one embodiment where the sensor system is integrated as an FPGA, or is coupled to an FPGA, automobile or vehicle specific information may be first obtained to build a vehicle specific history and operating conditions. This history may be used to customize the FPGA according to the vehicle specific history, operating conditions, and accordingly have custom temperature thresholds.

[0030] One having ordinary skill in the art will readily understand that the invention as discussed above may be practiced with steps in a different order, and / or with hardware elements in configurations which are different than those which are disclosed. Therefore, although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain modifications, variations, and alternative constructions would be apparent, while remaining within the spirit and scope of the invention. To determine the metes and bounds of the invention, therefore, reference should be made to the appended claims.

CLAIMS

I claim / We claim:

1. A method to control internal temperature of electronic components in automotive applications comprising:

applying an individual activity based temperature compensation scheme on a plurality of components wherein the scheme maintains the temperature of individual components within their operating temperature range.

2. The method of claim 1, wherein the scheme comprises:

sensing whether a component is in an idle state;

in response to the determination that the temperature of the component is below a first threshold, triggering a set of instructions to start a heating routine;

monitoring the temperature of the component, and determining whether the temperature of component reaches a second threshold or within a prescribed range of the second threshold; and

in response to the determination that the temperature of the component is either within a range of the second threshold, triggering a set of instructions to end the heating routine.

3. The method of claim 2, wherein monitoring the component is done continuously or at a predetermined interval.

4. The method of claim 2, wherein the heating routine is configured to control access to peripheral systems including a heating system.

5. The method of claim 4, wherein the heating routine is in a control feedback loop with battery components to monitor currently active and inactive components.

6. The method of claim 4, wherein the heating system includes additional components, that are activated by memory write and / or read operations, processor dummy operations and / or cellular device base station check routines / sub routines.

7. The method of claim 4, wherein the heating system is configured with a Field Programmable Gate Array ("FPGA"), or an Application Specific Integrated Circuit ("ASIC").

8. The method of claim 7, wherein vehicle specific information is used to build an information system relating to temperature, sensor, and from other inputs, wherein the information system is used to dynamically input the thresholds in the FPGA or the ASIC.

9. The method of claim 8, wherein the FPGA is programmed with a predefined threshold, and the predefined threshold is updated according actual operating conditions of a vehicle.

10. The method of claim 9, wherein the predefined threshold is based on vehicle testing information.

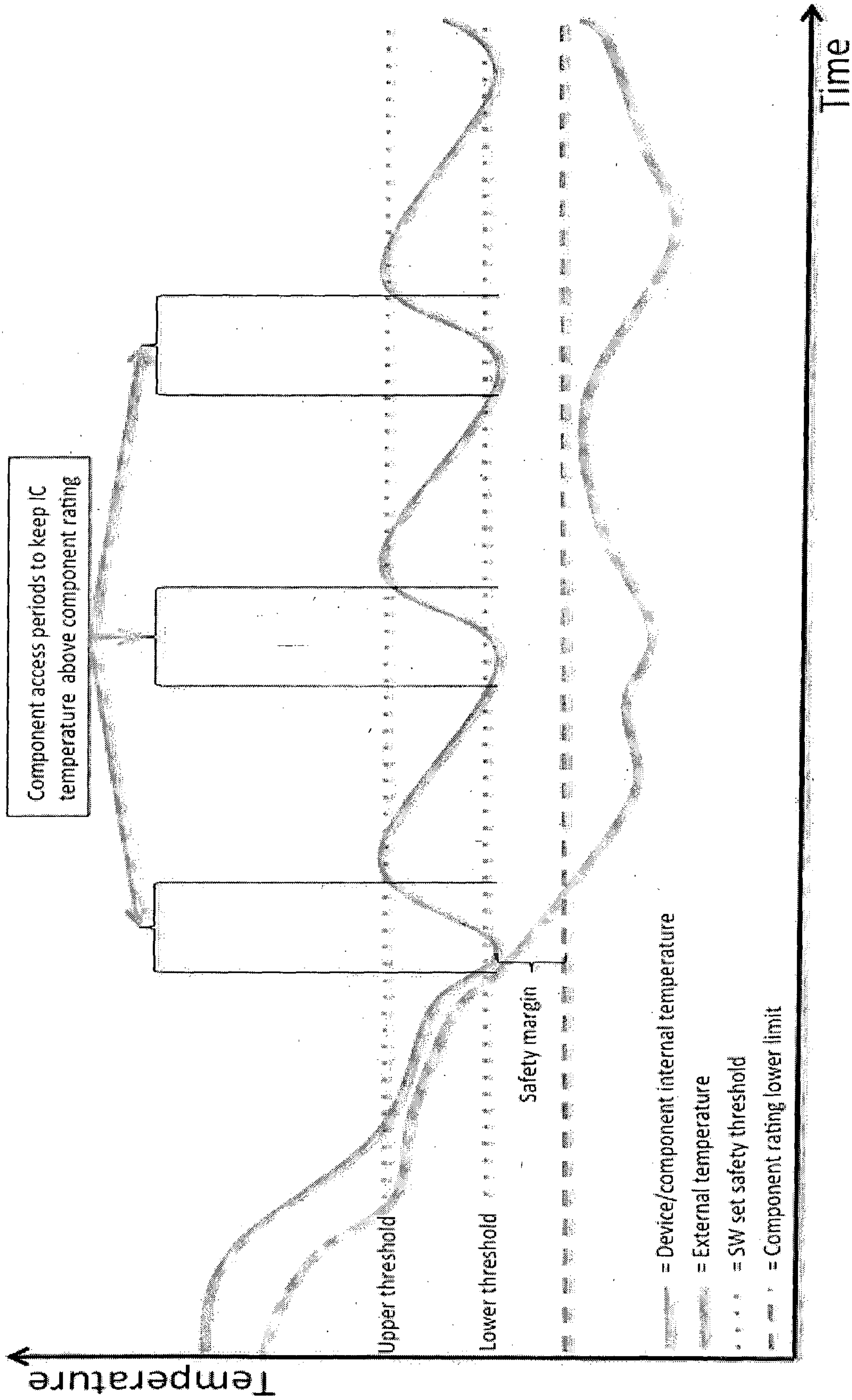

FIG.1

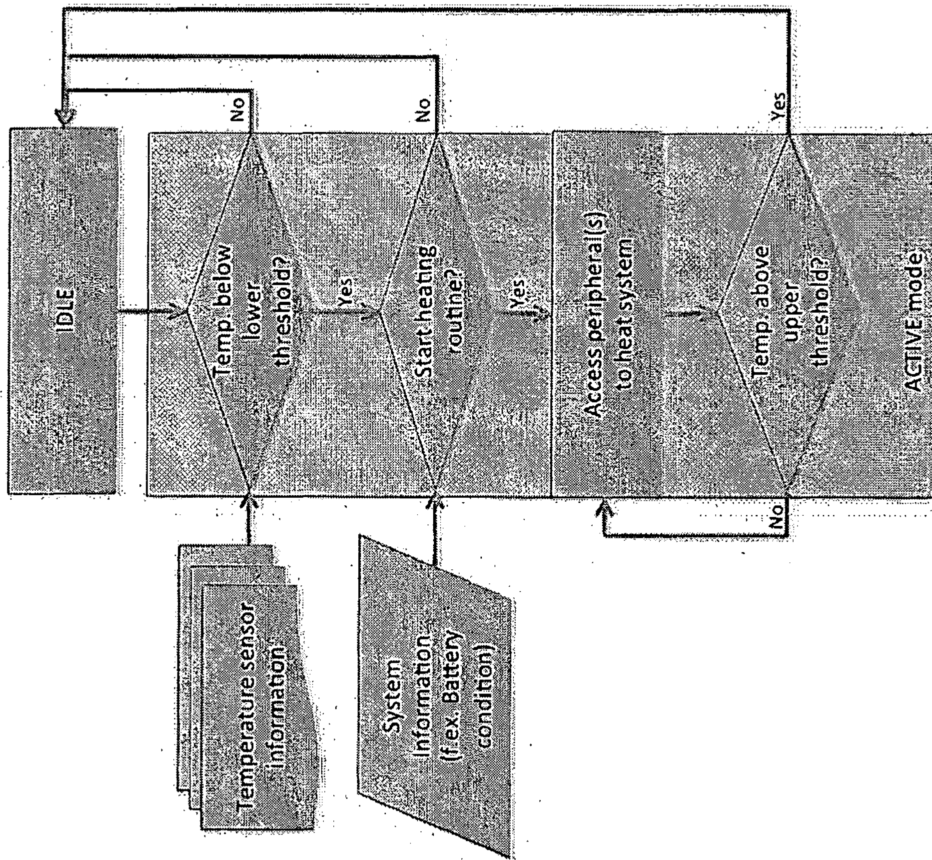

FIG.2