TECHNOLOGY REVIEW:

MOBILE DEVICE THERMAL MANAGEMENT

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications. We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application. In this issue our spotlight is on cooling applications for mobile devices. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors. Table 1 below lists the patents that will be reviewed in this issue.

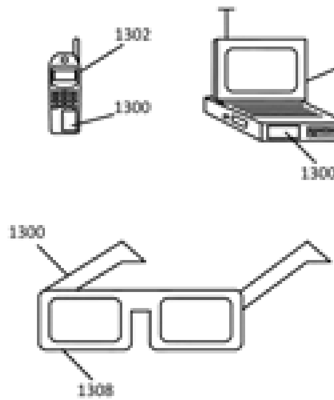
THERMAL MANAGEMENT OF AN ELECTRONIC DEVICE BASED ON A SENSATION MODEL

US 20140249690 A1, PARK, H.

Thermal management of electronic devices is an important factor in the design and operation of electronic devices. Thermal management is especially critical for portable handheld electronic devices (e.g., smart phones, tablets, wearable mobile device) because users holding/wearing the electronic devices are sensitive to the heat generated by the electronic devices. Traditionally, the thermal management of electronic devices relies on controlling the absolute temperature of the electronic devices. That is, an upper absolute temperature limit is specified for the electronic devices, and the thermal management controls the electronic device such that the electronic device is not allowed to operate and/or generate heat beyond the upper temperature limit. Thus, as long as the electronic device is operating below the upper absolute temperature limit, the thermal management will not limit, interfere or throttle the operation/activity of the electronic device. However,

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
US 20140249690 A1	Thermal Management of an Electronic Device Based on a Sensation Model	Park, H.	Sep 4, 2014
US 8595517 B2	Thermal Management of a Mobile Device with Ventless Housing	Riechel, P., et al.	Nov 26, 2013
US8554389 B2	Thermal Management Techniques in an Electronic Device	Cox, K., et al.	Oct 8, 2013

Table 1. Patents Reviewed Featuring Mobile Device Thermal Management



thermal management of an electronic device based solely on an upper temperature limit is inherently limited, and does not take into account other factors such as dynamic characterizations of human temperature sensation when performing thermal management.

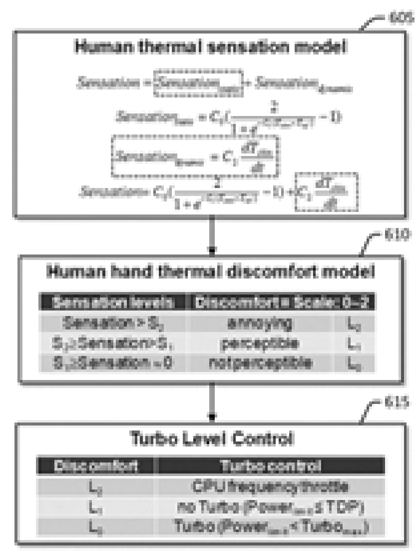
Therefore, there is a need for an improved thermal management of portable and/or wearable electronic devices that take into account other factors and consideration when performing thermal management. Various features, apparatus and methods described herein provide a thermal management of an electronic device based on sensation model.

What is claimed is:
A method for performing thermal management of an electronic device, comprising:
determining a sensation value based on (i) a temperature of the electronic device, and (ii) a temperature rate change of the electronic device; and associating based on the determined sensation value, a discomfort level from a plurality of discomfort levels to the electronic device, the discomfort level specifying a maximum allowed activity for a processing unit of the electronic device, at least one discomfort level being dynamically adjustable.

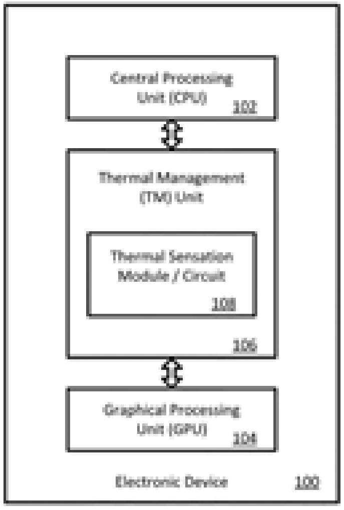
A first example provides a method for performing thermal management of an electronic device. The method determines a sensation value based on (i) a temperature of the electronic device, and (ii) a temperature rate change of the electronic device. The method associates based on the determined sensation value, a discomfort level from a plurality of discomfort levels to the electronic device. At least one discomfort level is dynamically adjustable. The discomfort level specifies a maximum allowed activity for a processing unit of the electronic device.

A second example provides an apparatus configured to perform thermal management of an electronic device. The apparatus includes a means for determining a sensation value based on (i) a temperature of the electronic device, and (ii) a temperature rate change of the electronic device. The apparatus also includes a means for associating based on the determined sensation value, a discomfort level from a plurality of discomfort levels to the electronic device, the discomfort level specifying a maximum allowed activity for a processing unit of the electronic device, at least one discomfort level being dynamically adjustable.

According to an aspect, the apparatus is incorporated into at least one of a music player, a video player, an entertainment unit, a navigation device, a communications device, a mobile device, a mobile phone, a smartphone, a personal digital assistant, a fixed location terminal, a tablet computer, a laptop computer, an eyeglass, a watch and/or wearable device.



A third example provides a computer readable storage medium that includes one or more instructions for performing thermal management of an electronic device, which when executed by at least one processor, causes the at least one processor to: determine a sensation value based on (i) a temperature of the electronic device, and (ii) a temperature rate change of the electronic device; and associate based on the determined sensation value, a discomfort level from a plurality of discomfort levels to the electronic device, the discomfort level specifying a maximum allowed activity for a processing unit of the electronic device, at least one discomfort level being dynamically adjustable.



According to an aspect, the sensation value is based on an adjustable sensation model that includes a static sensation model and a dynamic sensation model. In some implementations, the adjustable sensation model is based on at least one thermal coefficient constant. In some implementations, at least one thermal coefficient constant is adjustable. The adjustable thermal coefficient constant specifies a range of temperature values for an adjustable discomfort level. In some implementations, the range of temperature values for the adjustable discomfort level comprises a maximum temperature. The maximum temperature is based on a minimum value of one of at least a sensation value, regulation limit, and/or manufacturer limit.

THERMAL MANAGEMENT OF A MOBILE DEVICE WITH VENTLESS HOUSING

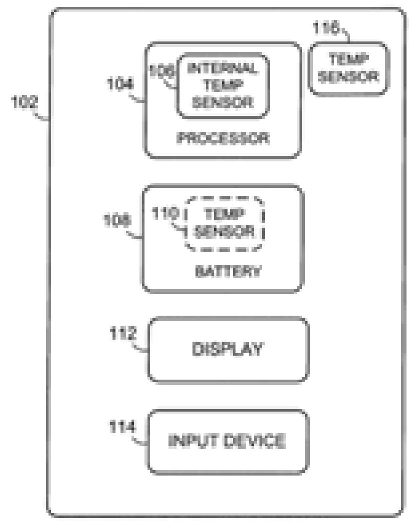
US 8595517 B2, RIECHEL, P., ET AL.

Due to their relatively small size and complex circuitry, microprocessors tend to generate significant heat. This heat can become problematic when the microprocessor is situated in an enclosure have little or no ventilation. The heat must be controlled or dissipated to prevent damage to the microprocessor and to the surrounding circuitry. Many microprocessors contain heat regulating devices that prevent the microprocessor from overheating.

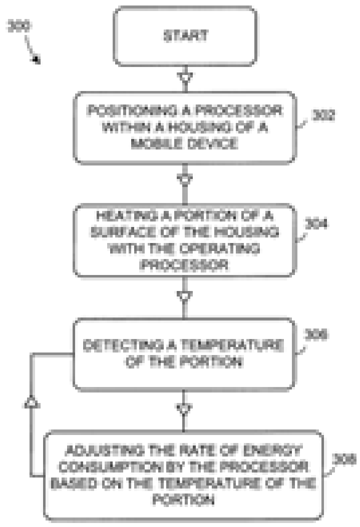
In one aspect, the invention is embodied in a mobile device including a housing having a plurality of surfaces. A processor is located within the housing. The processor heats a portion of one or more of the surfaces of the housing. A temperature sensor detects a temperature of the portion of the surface. The rate at which energy is consumed by the processor is adjusted based on the temperature of the portion of the surface of the housing. In one embodiment, the rate at which energy is consumed by the processor is adjusted by modifying at least one of a duty cycle of the processor, a clock speed of the processor and a voltage supplied to the processor.

In one embodiment, the mobile device includes a second temperature sensor for detecting the temperature of the processor. In one embodiment, a second temperature sensor detects a temperature of a battery electrically coupled to the processor. The portion can correspond to an area of the at least one surface having the highest temperature.

In one embodiment, a control loop continually adjusts the rate at which energy is consumed by the processor based on a thermal characterization of the mobile device. The housing can be substantially sealed. In one embodiment, at least one of the plurality of surfaces is thermally conductive. The thermally conductive surface conducts heat from the processor. In one embodiment, at least one of the plurality of surfaces is substantially thermally insulating.



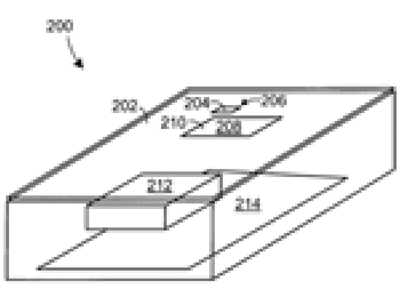
In another aspect, the invention is embodied in a method including positioning a processor within a housing having a plurality of surfaces. The processor heats a portion of at least one of the plurality of surfaces of the housing. The temperature of the portion is detected. The rate at which energy is consumed by the processor duty is adjusted based on the temperature of the portion.



In one embodiment, the rate at which energy is consumed by the processor is adjusted by modifying at least one of a duty cycle of the processor, a clock speed of the processor and a voltage supplied to the processor.

In one embodiment, method further comprises adjusting the rate at which energy is consumed by the processor based on a temperature of the processor. In one embodiment, the temperature of the processor is detected. In another embodiment, a temperature of a battery electrically coupled to the processor is detected.

In one embodiment, the portion corresponds to an area of the at least one surface having the highest temperature. The method can further include continually adjusting the rate at which energy is consumed by the processor based on a thermal characterization of the mobile device. The housing can be substantially sealed. In one embodiment, heat is conducted from the processor with at least one of the plurality of surfaces.

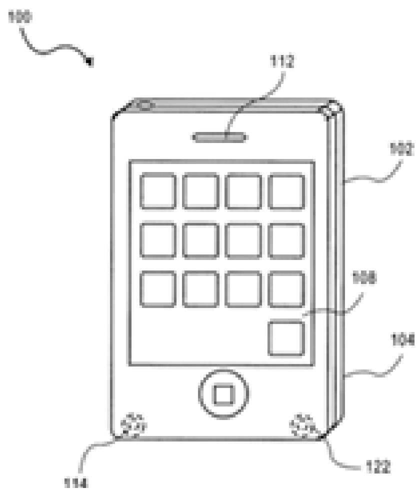


THERMAL MANAGEMENT TECHNIQUES IN AN ELECTRONIC DEVICE

US 8554389 B2, COX, K., ET AL.

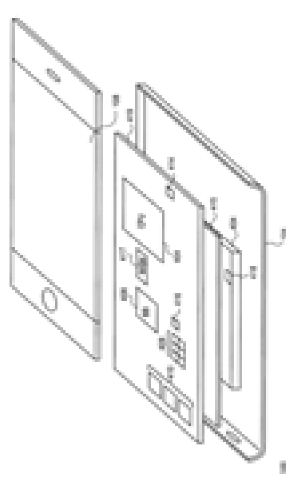
A thermal manager has a digital filter whose input is to receive raw temperature values from a sensor and whose output is to provide processed or filtered temperature values according to a filter function that correlates temperature at the sensor with temperature at another location in the device. The thermal manager has a look-up table that further correlates temperature at the sensor with temperature at the other location. The look-up table contains a list of processed temperature sensor values, and/or a list of temperatures representing the temperature at the other location, and their respective power consumption change commands. The thermal manager accesses the look-up table using selected, filtered temperature values, to identify their respective power consumption change commands. The latter are then evaluated and may be applied, to mitigate a thermal at the other location. Other embodiments are also described and claimed.

An embodiment of the invention is directed to an improved thermal management process running in a portable handheld wireless communications device that has relatively confined internal space, to manage the device's own thermal behavior but without significantly impacting the user experience. There are at least two relevant aspects to such a process. First, the behavior of the device is managed so that the temperature of the device's battery (or other rechargeable main power source) stays within a given predefined range. See, e.g. Certification Requirements for Battery System Compliance to IEEE 1725, October 2007, Revision 1.4 (CTIA Certification Program). This is because battery temperature may quickly rise to undesirable levels during even normal operation of the device, e.g. when using a device that has been left inside a parked automobile in the sun, to make a cellular phone call. In part, this may be due to the operation of certain power hungry integrated circuit components of the device, such as the RF power amplifier (PA) that drives the device's cellular network RF communications antenna. For example, the RF PA often responds to requests from a base station, with which the device is registered, to increase its RF output power if the base station determines that signal from the device is weakening for any reason. This, together with the normal current drawn by the remaining electrical components, may significantly increase the heat that must



be dissipated, due to the electrical power consumption by the RF PA, thereby causing the battery to quickly heat up due to its relative proximity to the RF PA.

A second thermal arena to monitor and manage in the device is the device's external case temperature. This should also be kept in a predefined range, e.g. as specified by Underwriters Laboratories (UL) for consumer grade cellular telephone handsets. During normal operation, the external case of the device should not become so warm as to become uncomfortable for the user, e.g. while it is being held in the users hand or against the user's ear. The external case may be heated by any power consumed within the device, and the hottest points on the external case will most likely be in proximity to the circuitry with the highest concentration of power dissipation. In one embodiment, this may be the RF PA, as in the example above, or it may be another component or group of components, such as the application processor in a mobile telephone or smart phone.



What is claimed is:

1. A method for thermal management of an electronic device, comprising:

Obtaining a plurality of temperature readings from a temperature sensor that is located in a device at a location that is remote from a target location in the device;

Processing by a digital filter the plurality of temperature readings wherein the digital filter estimates a relationship over time between temperature at the remote location and temperature at the target location;

computing estimates of temperature at the target location using the processed temperature readings by converting the processed temperature readings using a predefined mathematical relationship between an estimated target location temperature variable and a processed temperature reading variable; and

using the computed estimates of the target location temperature to access a look up table and thereby identify power consumption commands, wherein the look up table contains a) a plurality of values all associated with the target location temperature and b) a plurality of power consumption commands, respectively, that include i) a plurality of no-change commands and ii) at least one change command that limits or reduces power consumption of a component in the device.

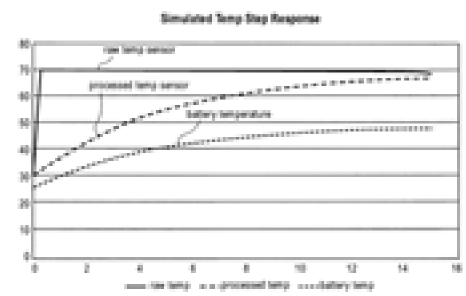


FIG. 1