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(54) INFORMATION PROCESSING APPARATUS

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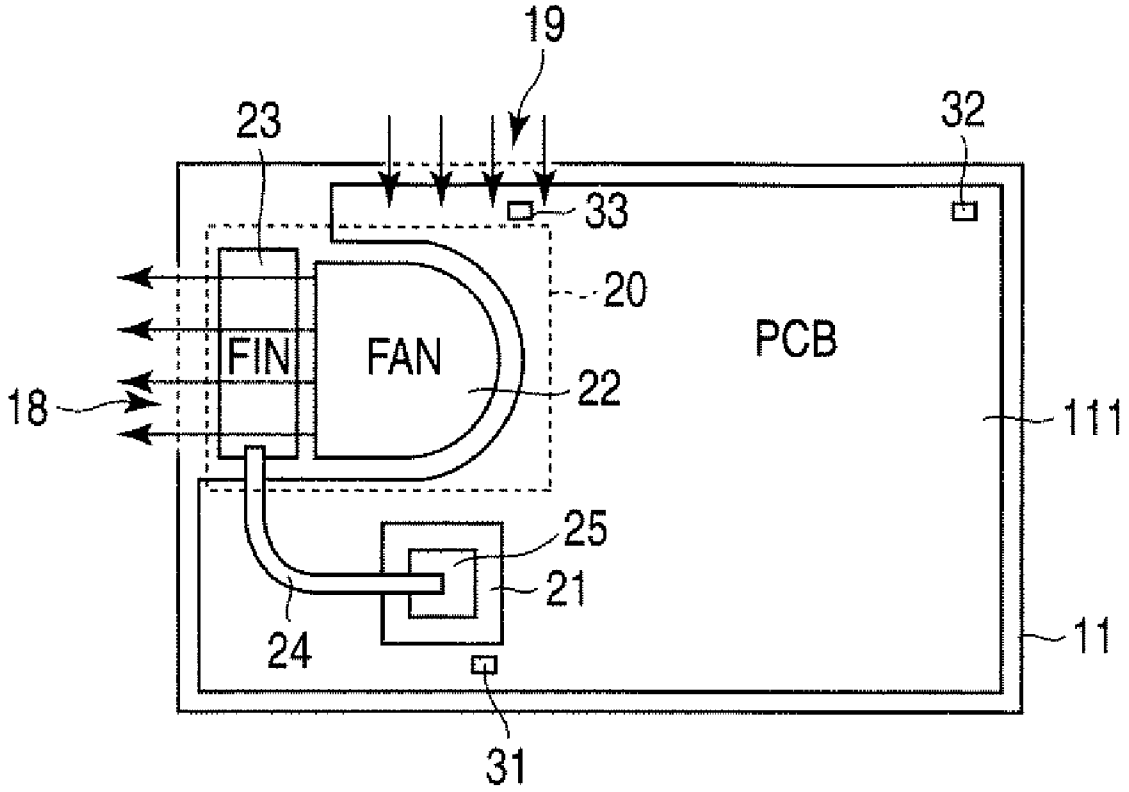
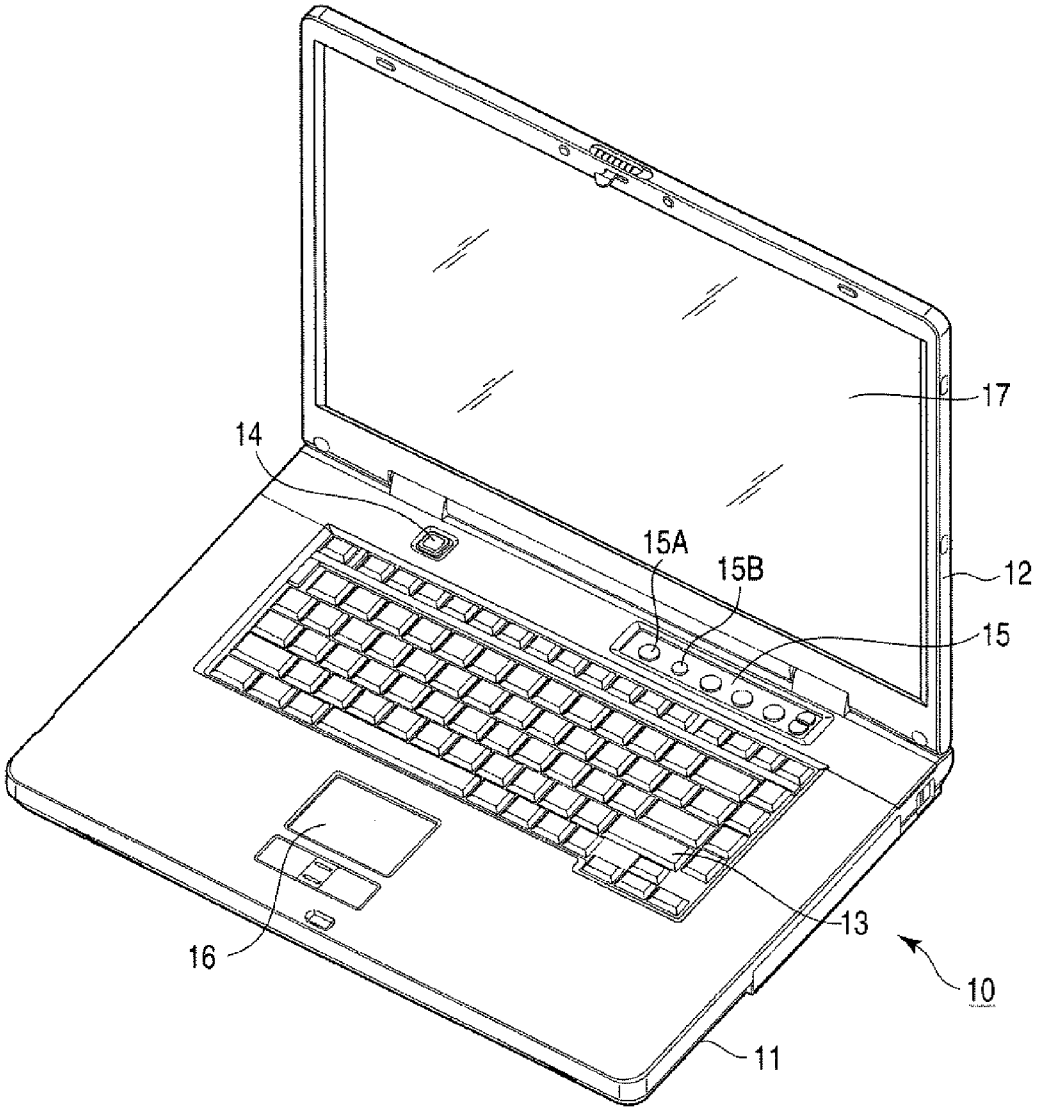
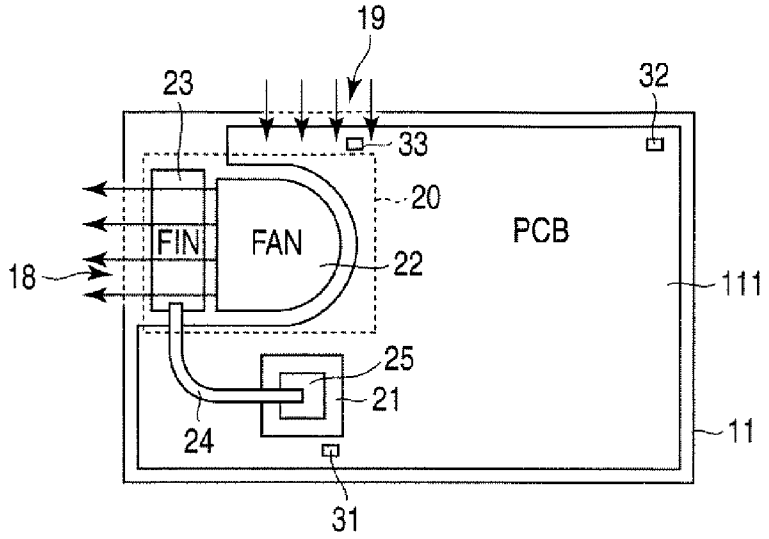
(57) ABSTRACT

According to one embodiment, an information processing apparatus includes a heating device, a heat radiation module, a first temperature sensor configured to detect a temperature at a first position on a printed circuit board, a second temperature sensor configured to detect a temperature at a second position on the printed circuit board, which is farther from the heating device than the first position, a temperature difference detection module configured to detect a temperature difference which is obtained by subtracting the temperature at the second position from the temperature at the first position, and a performance determination module configured to execute a monitoring process of monitoring the temperature difference between the temperature at the first position and the temperature at the second position, and to determine whether a performance of the heat radiation module has lowered or not.

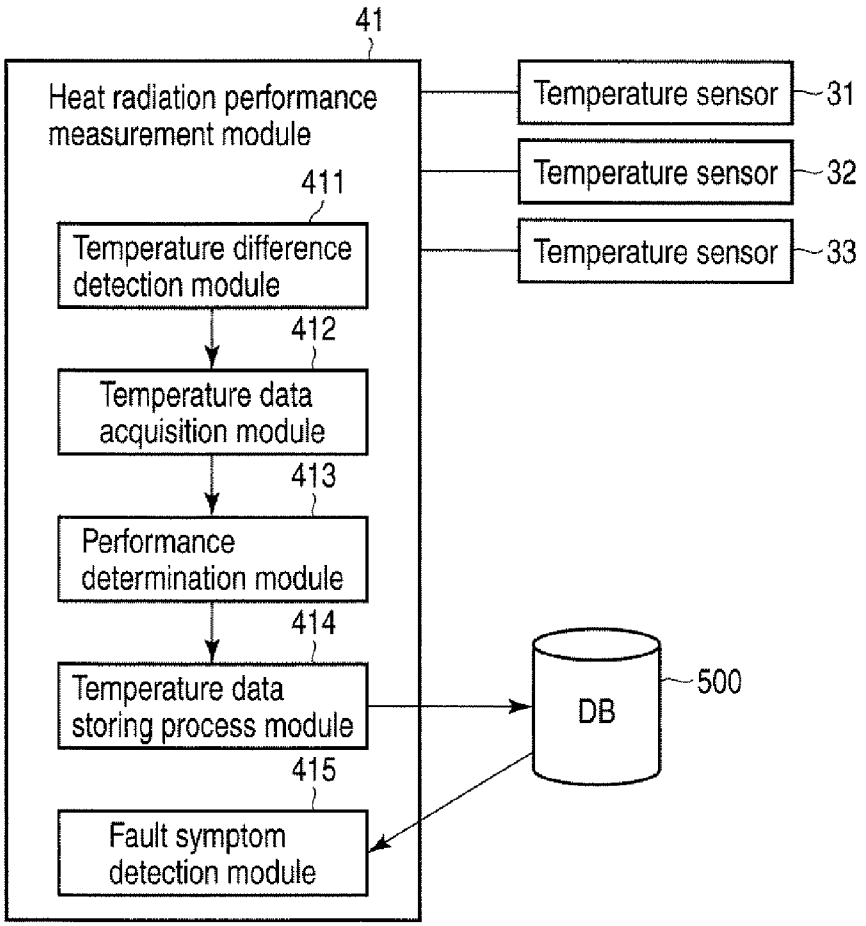




F I G. 1


19
23
32
33
20
FIN
FAN
PCB
18
22
111
25
21
24
11
31

F I G. 2


41
Heat radiation performance measurement module
411
Temperature difference detection module
412
Temperature data acquisition module
413
Performance determination module
414
Temperature data storing process module
415
Fault symptom detection module
Temperature sensor
31
Temperature sensor
32
Temperature sensor
33
DB
500

F I G. 3

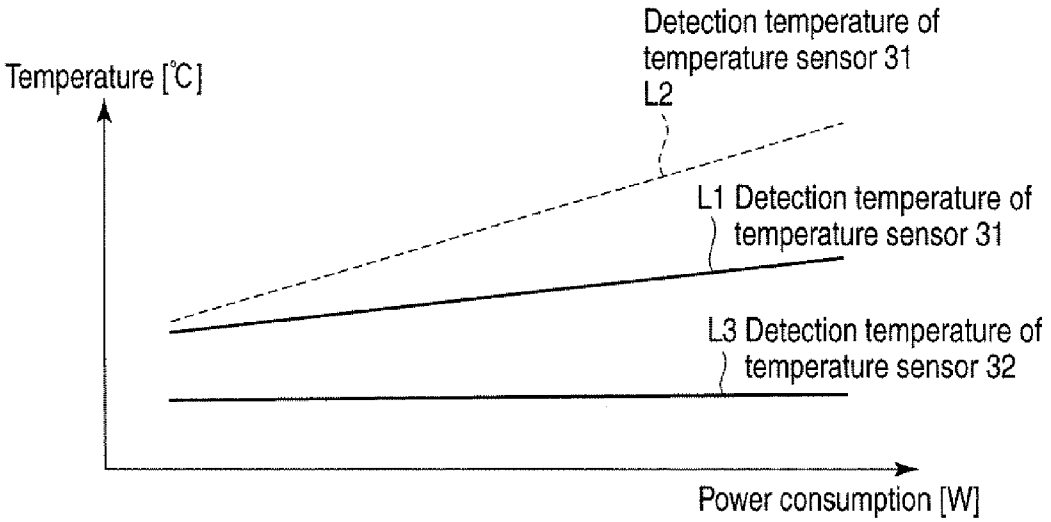

Temperature [℃]
Detection temperature of
temperature sensor 31
L2
L1 Detection temperature of
temperature sensor 31
L3 Detection temperature of
temperature sensor 32
Power consumption [W]

FIG. 4

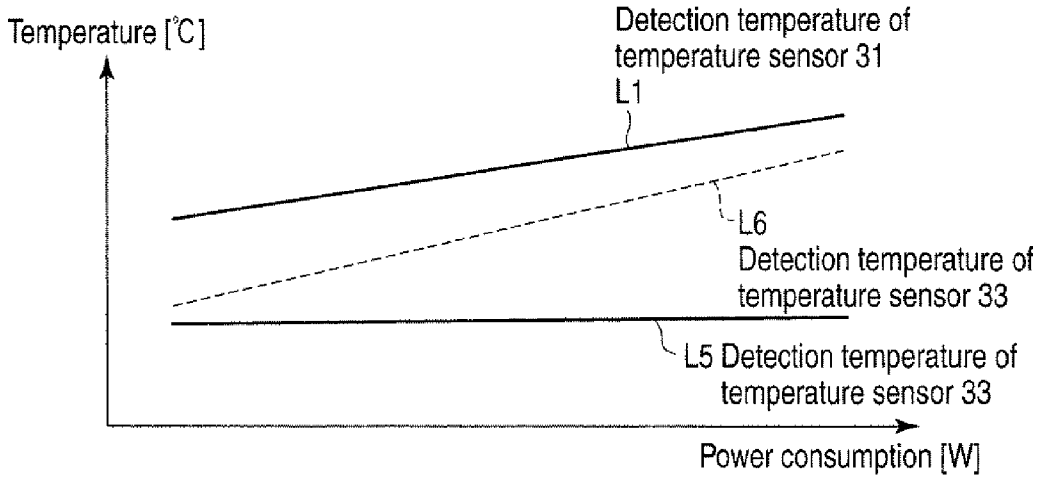
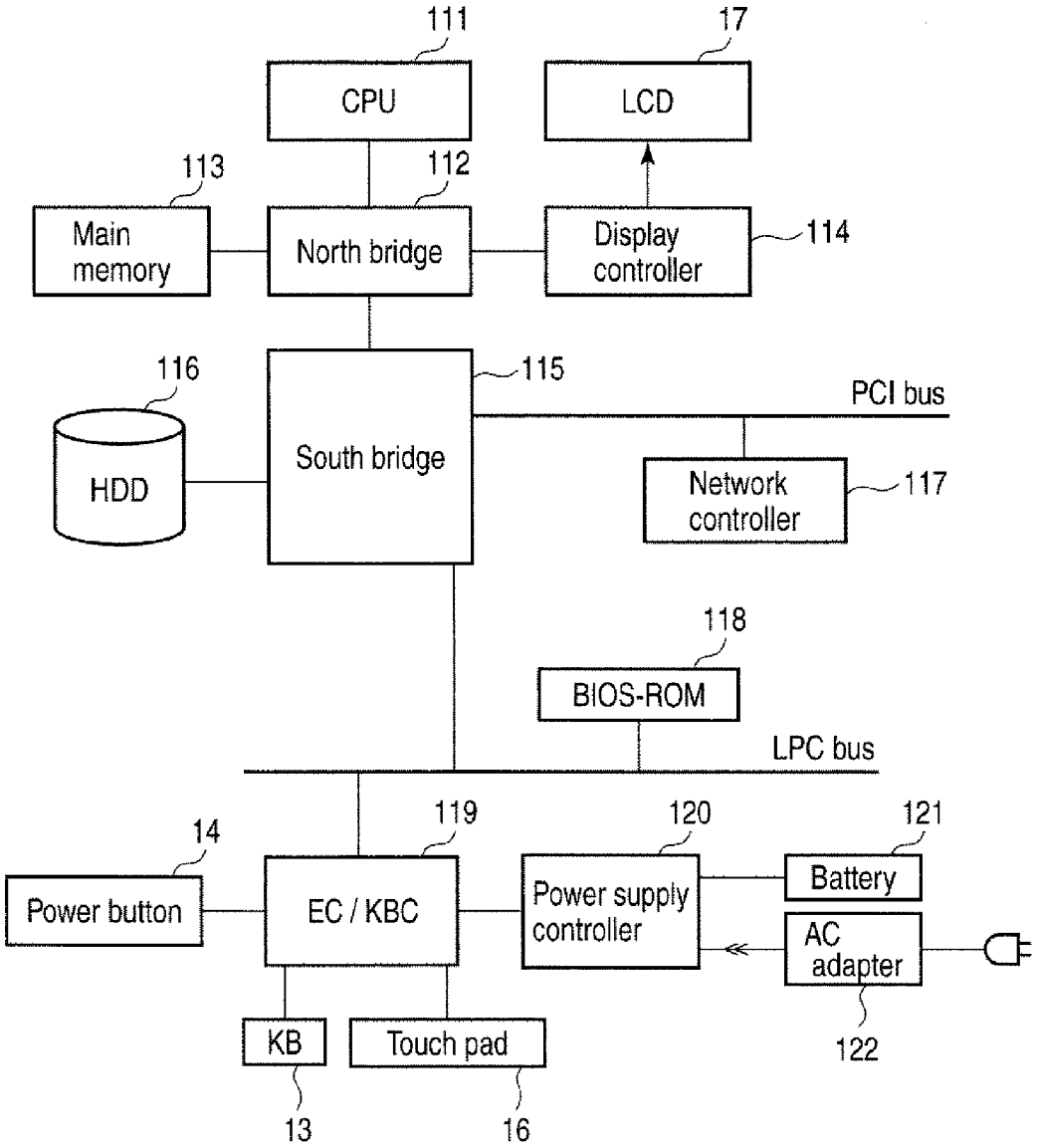
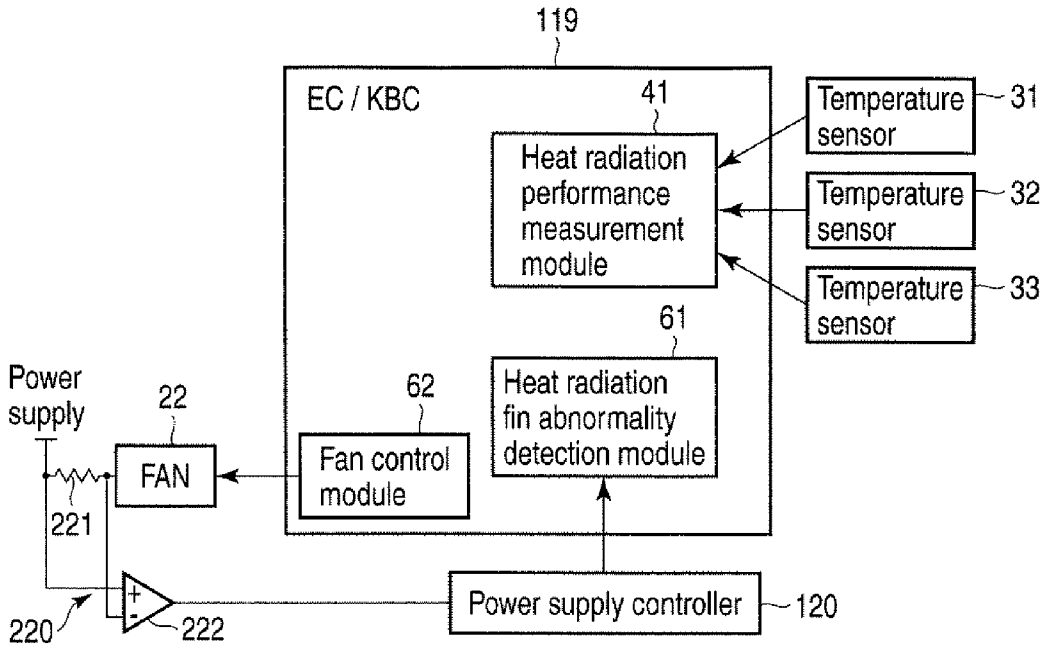

Temperature [℃]
Detection temperature of
temperature sensor 31
L1
L6
Detection temperature of
temperature sensor 33
L5 Detection temperature of
temperature sensor 33
Power consumption [W]

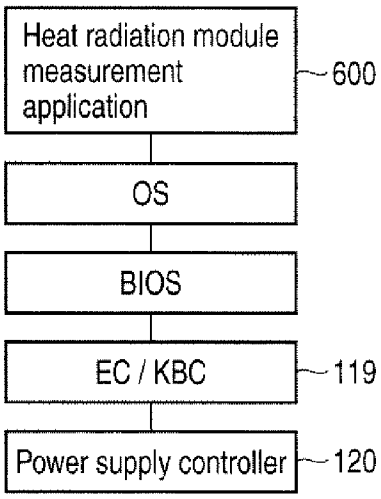
FIG. 5


111
CPU
17
LCD
113
Main memory
112
North bridge
Display controller
114
116
HDD
115
South bridge
PCI bus
Network controller
117
118
BIOS-ROM
LPC bus
14
Power button
119
EC / KBC
120
Power supply controller
121
Battery
AC adapter
122
KB
13
Touch pad
16

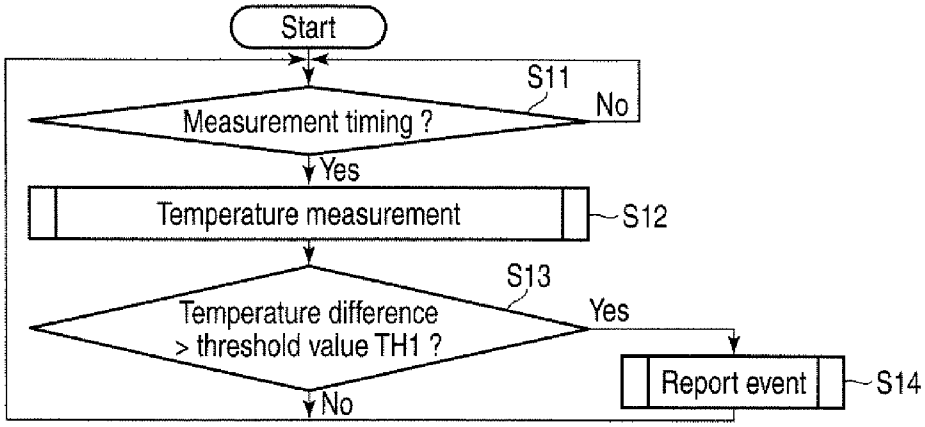
F I G. 6


119
EC / KBC
41
Heat radiation performance measurement module
Temperature sensor
31
Temperature sensor
32
Temperature sensor
33
61
Heat radiation fin abnormality detection module
62
Fan control module
Power supply
22
FAN
221
220
222
Power supply controller
120

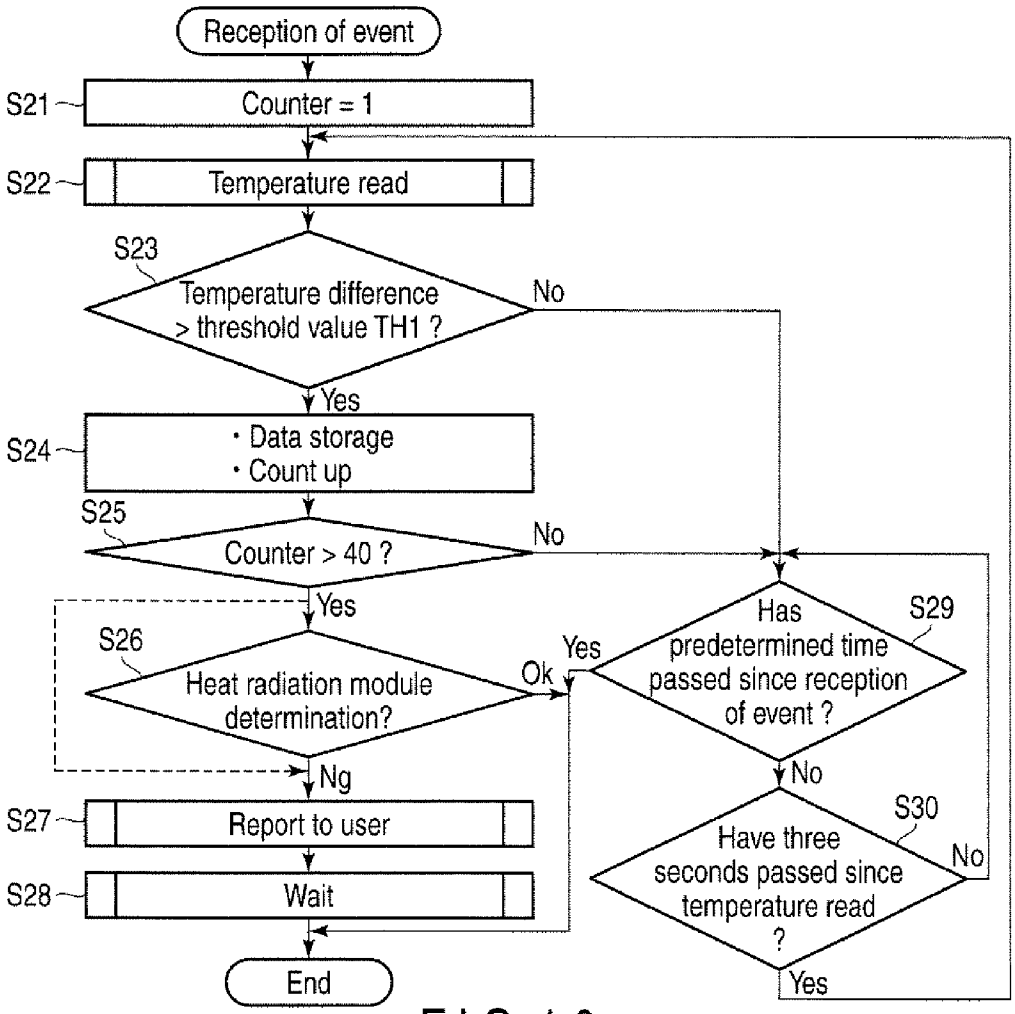
F I G. 7


Heat radiation module measurement application
600
OS
BIOS
EC / KBC
119
Power supply controller
120

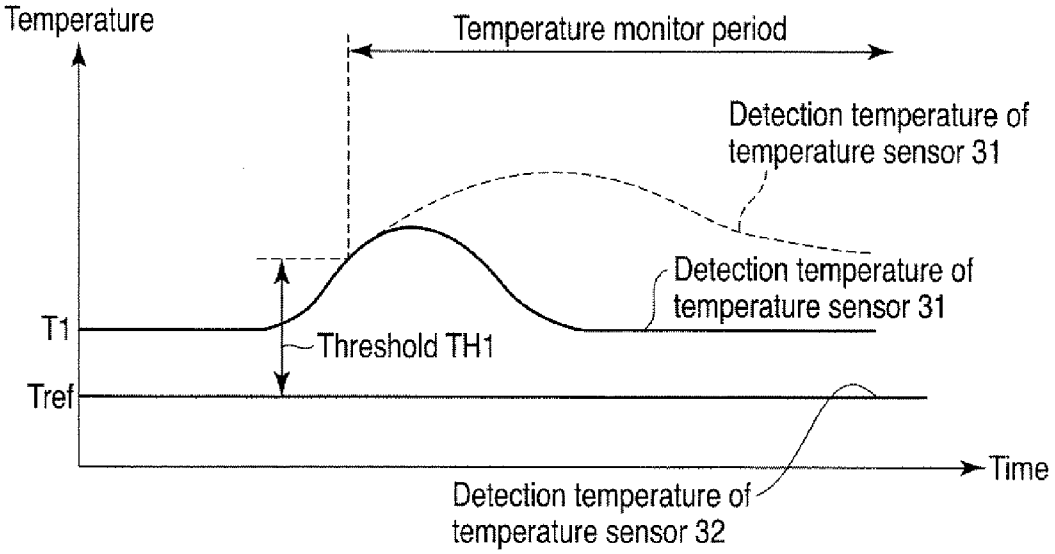
F I G. 8


Start
S11
Measurement timing ?
No
Yes
Temperature measurement
S12
S13
Temperature difference
> threshold value TH1 ?
Yes
No
Report event
S14

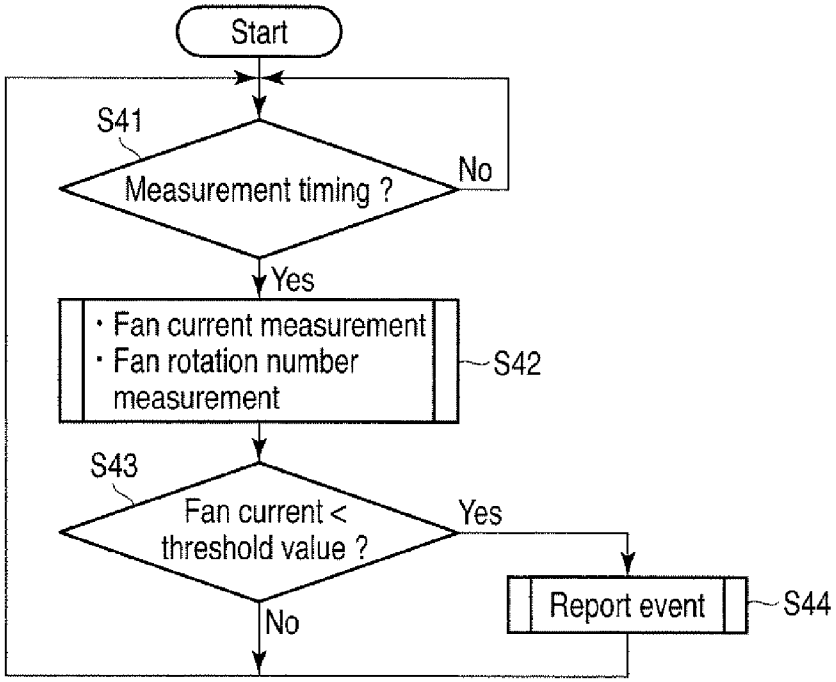
F I G. 9


Reception of event
S21
Counter = 1
S22
Temperature read
S23
Temperature difference
> threshold value TH1 ?
No
Yes
S24
• Data storage
• Count up
S25
Counter > 40 ?
No
Yes
S26
Heat radiation module
determination?
Ok
Yes
Ng
S27
Report to user
S28
Wait
End
Has
predetermined time
passed since reception
of event ?
S29
No
S30
Have three
seconds passed since
temperature read
?
No
Yes

F I G. 1 0


Temperature
Temperature monitor period
Detection temperature of temperature sensor 31
Detection temperature of temperature sensor 31
T1
Threshold TH1
Tref
Time
Detection temperature of temperature sensor 32

F I G. 1 1


Start
S41
Measurement timing ?
No
Yes
· Fan current measurement
· Fan rotation number measurement
S42
S43
Fan current < threshold value ?
Yes
No
Report event
S44

F I G. 1 2

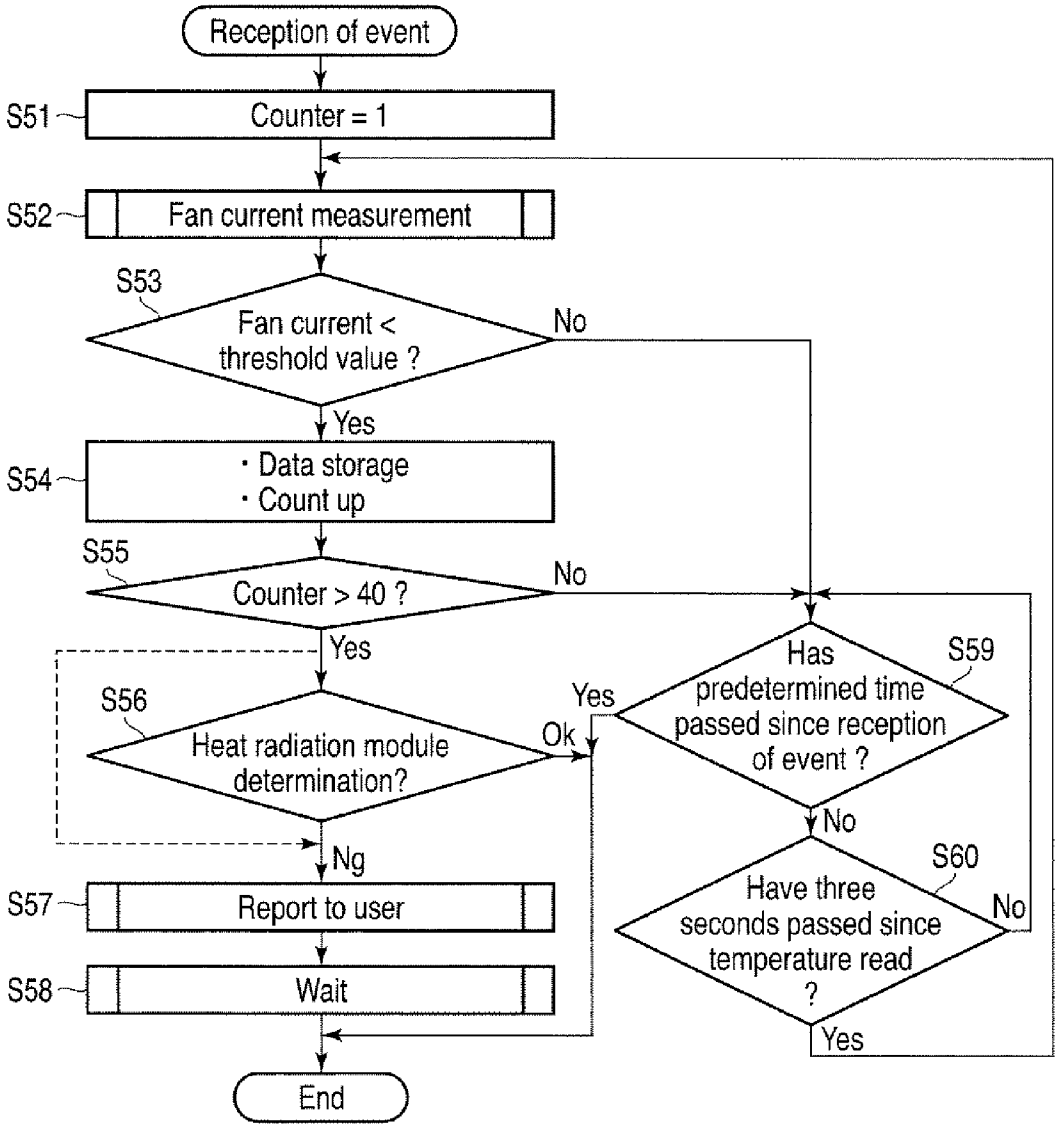

Reception of event
S51
Counter = 1
S52
Fan current measurement
S53
Fan current < threshold value ?
No
Yes
S54
・Data storage
・Count up
S55
Counter > 40 ?
No
Yes
S56
Heat radiation module determination?
Ok
Ng
S57
Report to user
S58
Wait
End
Yes
Has predetermined time passed since reception of event ?
S59
No
S60
Have three seconds passed since temperature read ?
No
Yes

FIG. 13

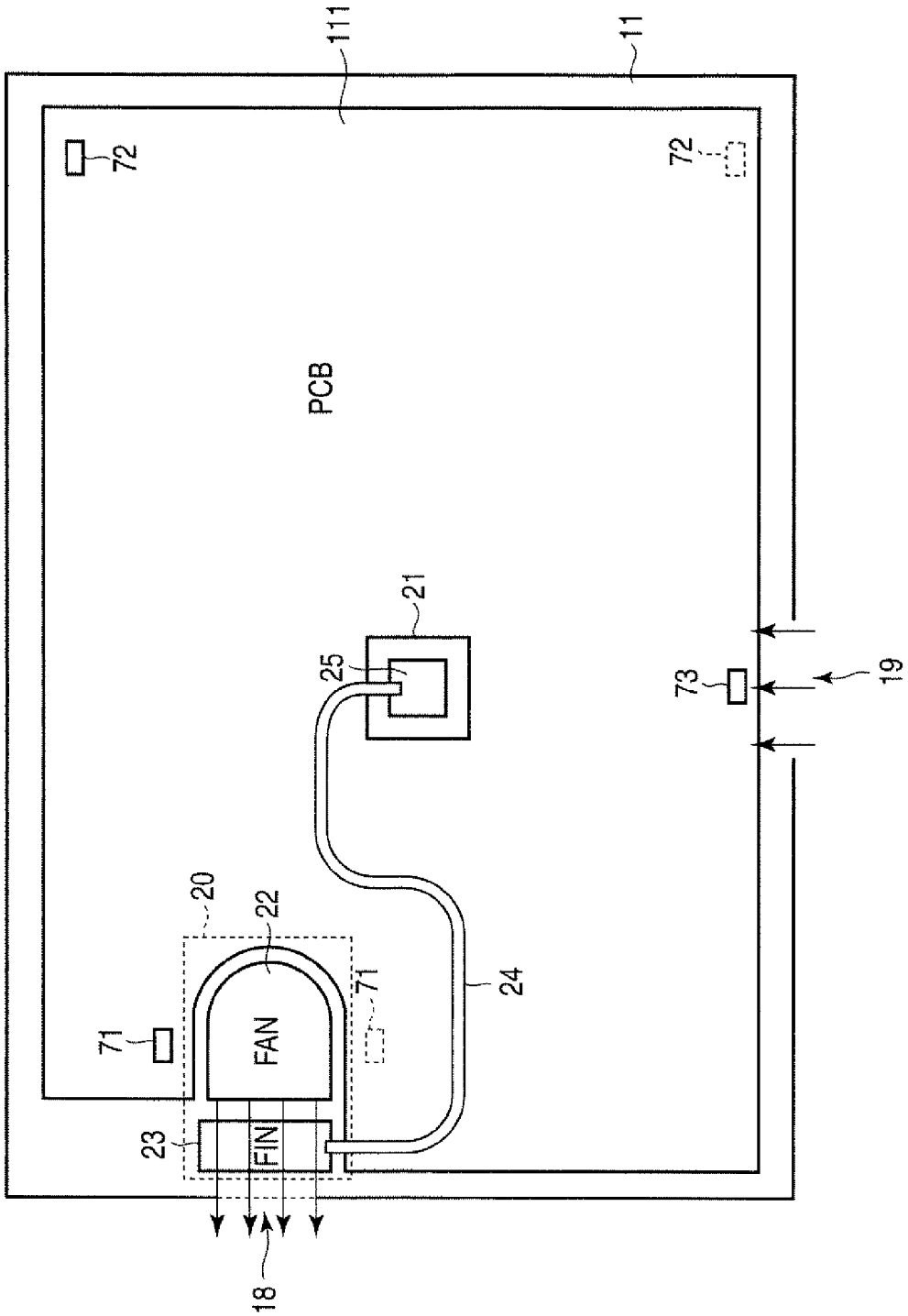


FIG. 14

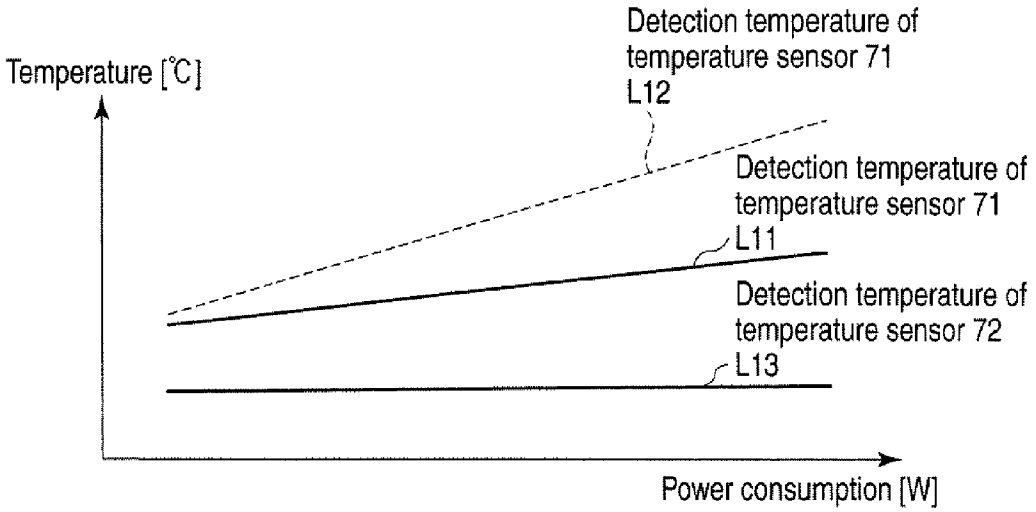

Temperature [℃]
Detection temperature of temperature sensor 71
L12
Detection temperature of temperature sensor 71
L11
Detection temperature of temperature sensor 72
L13
Power consumption [W]

FIG. 15

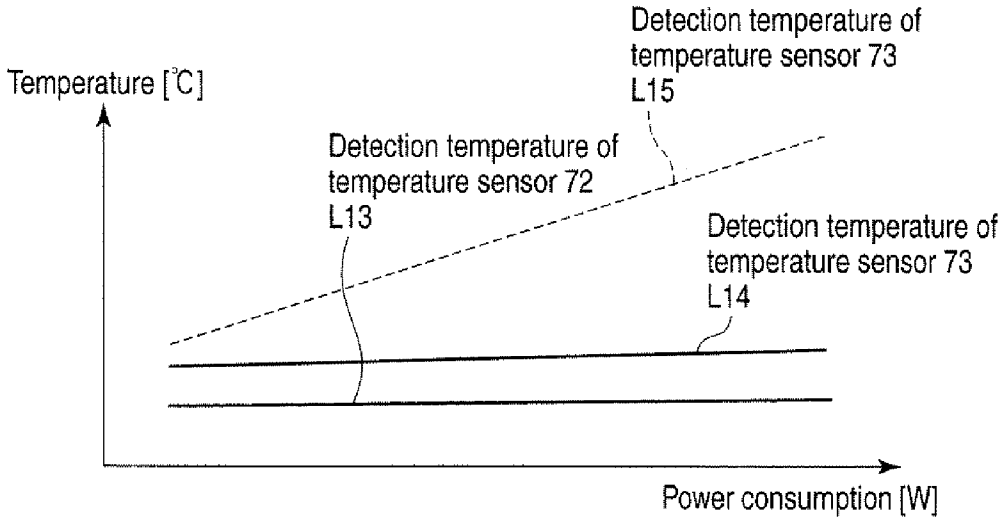

Temperature [℃]
Detection temperature of temperature sensor 73
L15
Detection temperature of temperature sensor 72
L13
Detection temperature of temperature sensor 73
L14
Power consumption [W]

FIG. 16

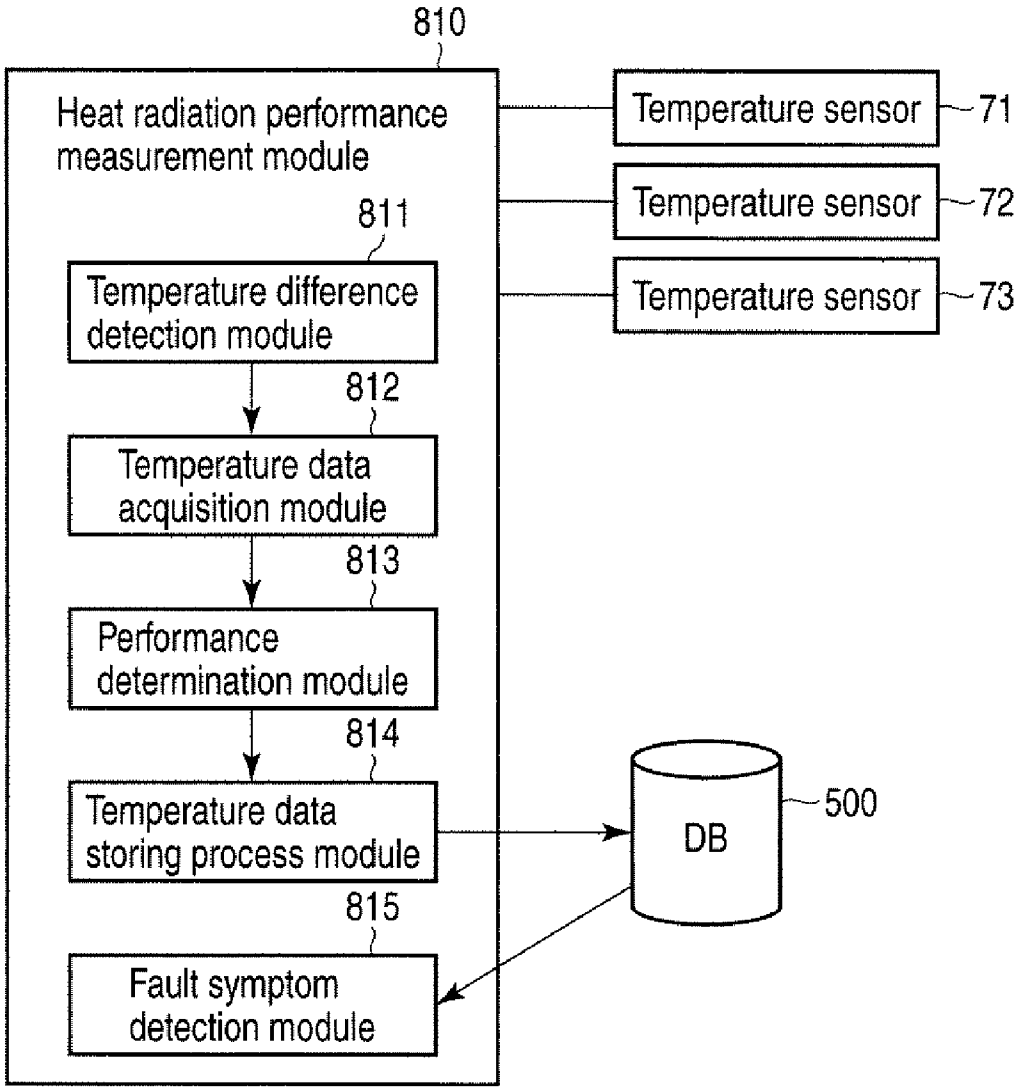

810
Heat radiation performance measurement module
811
Temperature difference detection module
812
Temperature data acquisition module
813
Performance determination module
814
Temperature data storing process module
815
Fault symptom detection module
Temperature sensor
71
Temperature sensor
72
Temperature sensor
73
DB
500

FIG. 17

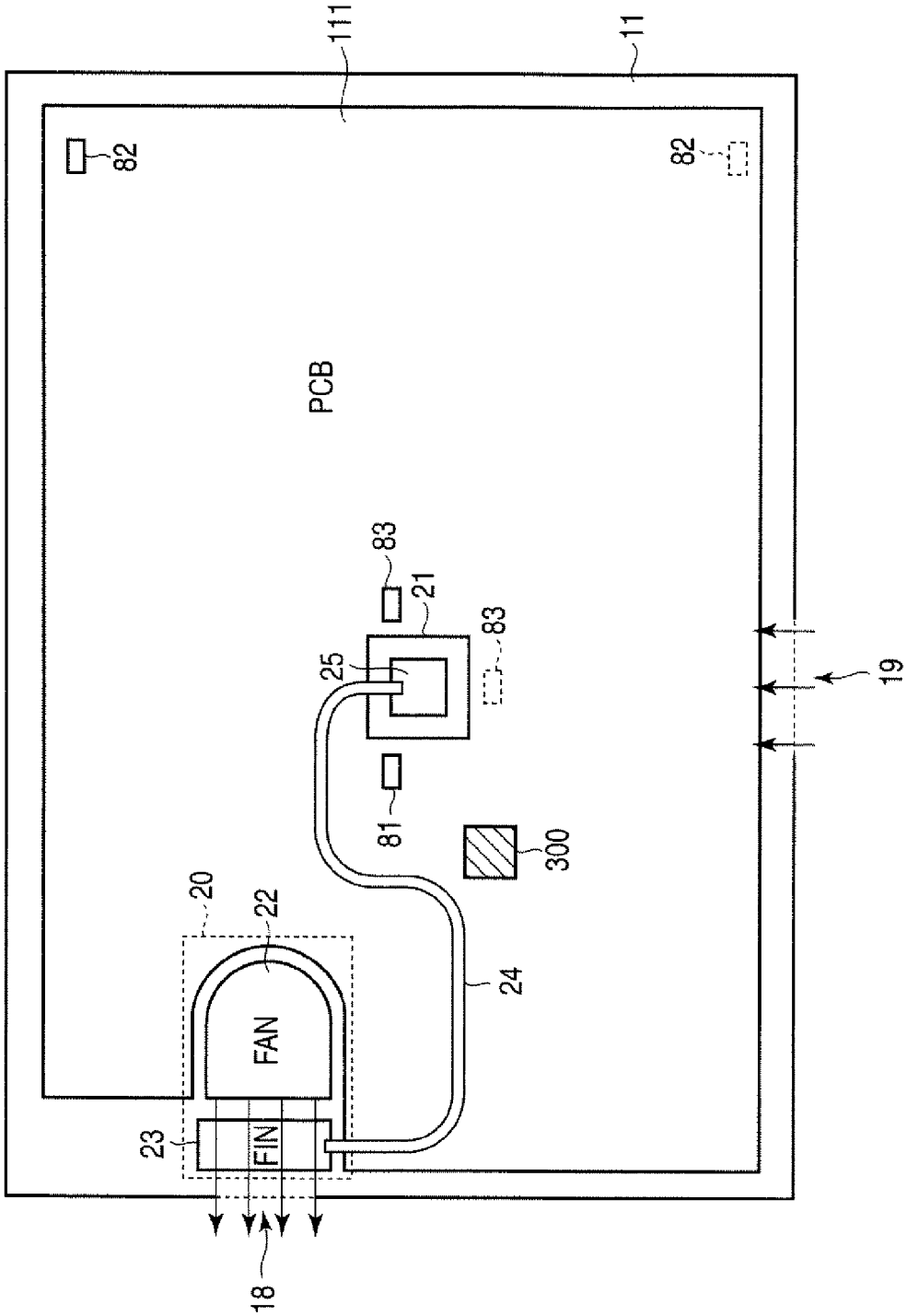


FIG. 18

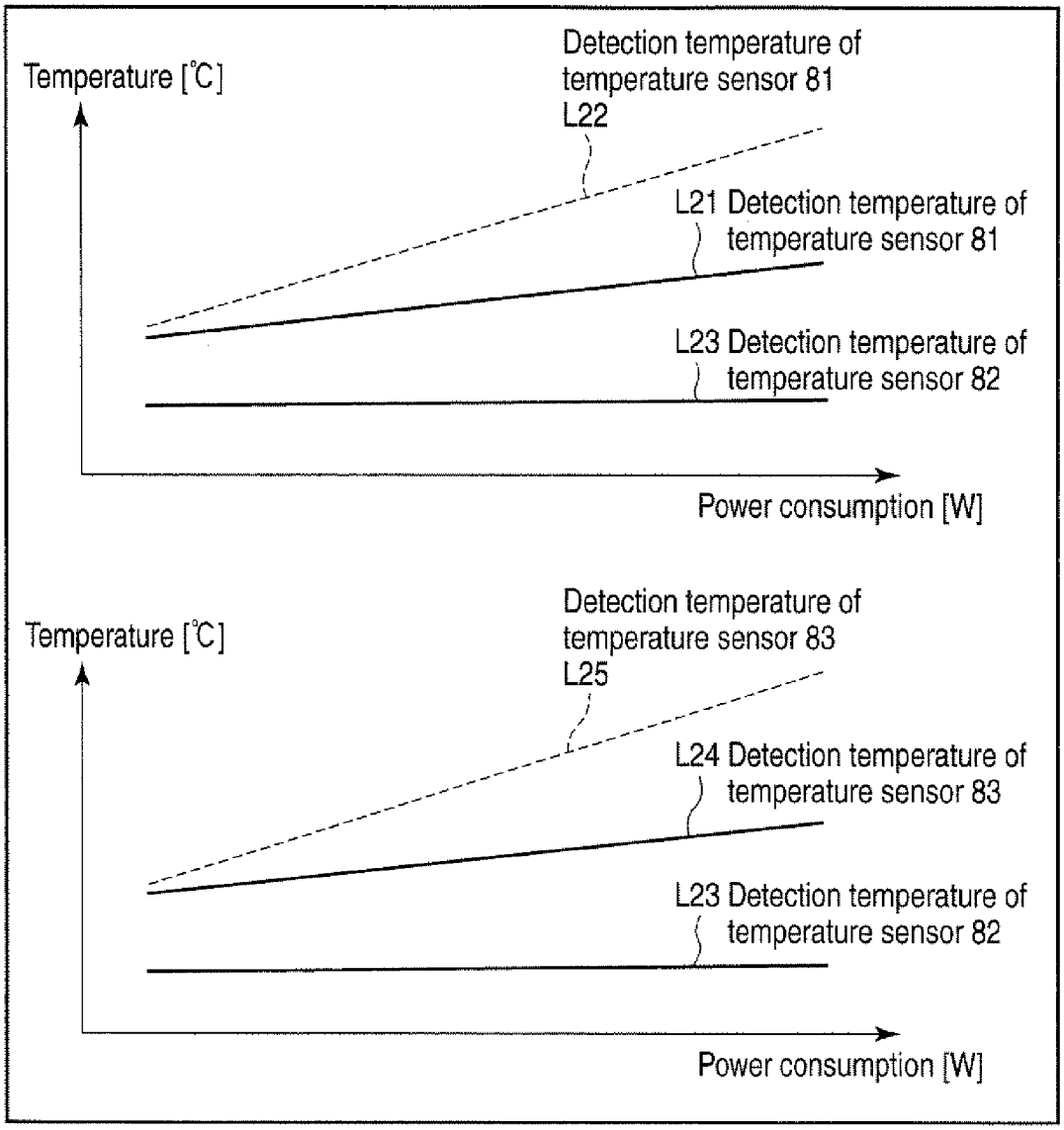

Temperature [℃]
Detection temperature of temperature sensor 81
L22
L21 Detection temperature of temperature sensor 81
L23 Detection temperature of temperature sensor 82
Power consumption [W]
Temperature [℃]
Detection temperature of temperature sensor 83
L25
L24 Detection temperature of temperature sensor 83
L23 Detection temperature of temperature sensor 82
Power consumption [W]

FIG. 19

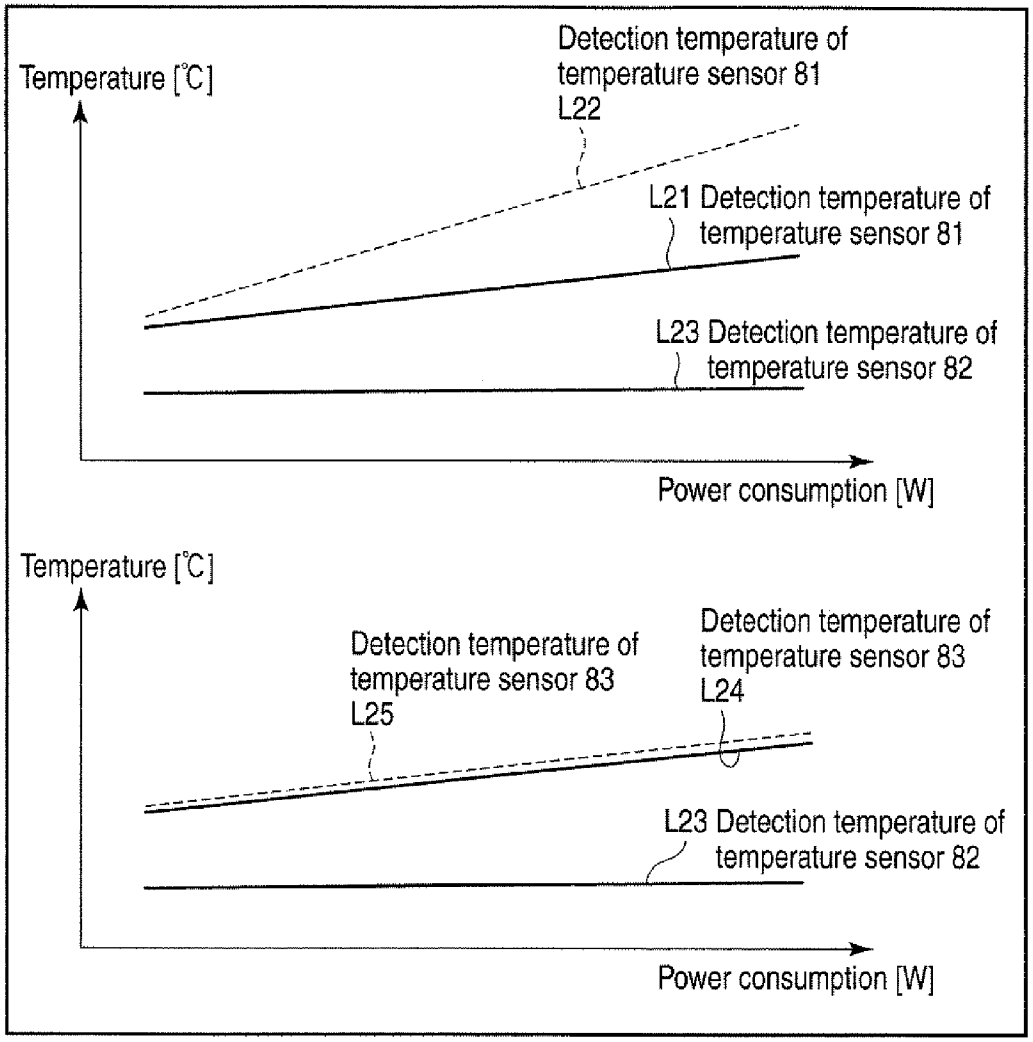

Temperature [℃]
Detection temperature of temperature sensor 81
L22
L21 Detection temperature of temperature sensor 81
L23 Detection temperature of temperature sensor 82
Power consumption [W]
Temperature [℃]
Detection temperature of temperature sensor 83
L25
Detection temperature of temperature sensor 83
L24
L23 Detection temperature of temperature sensor 82
Power consumption [W]

FIG. 20

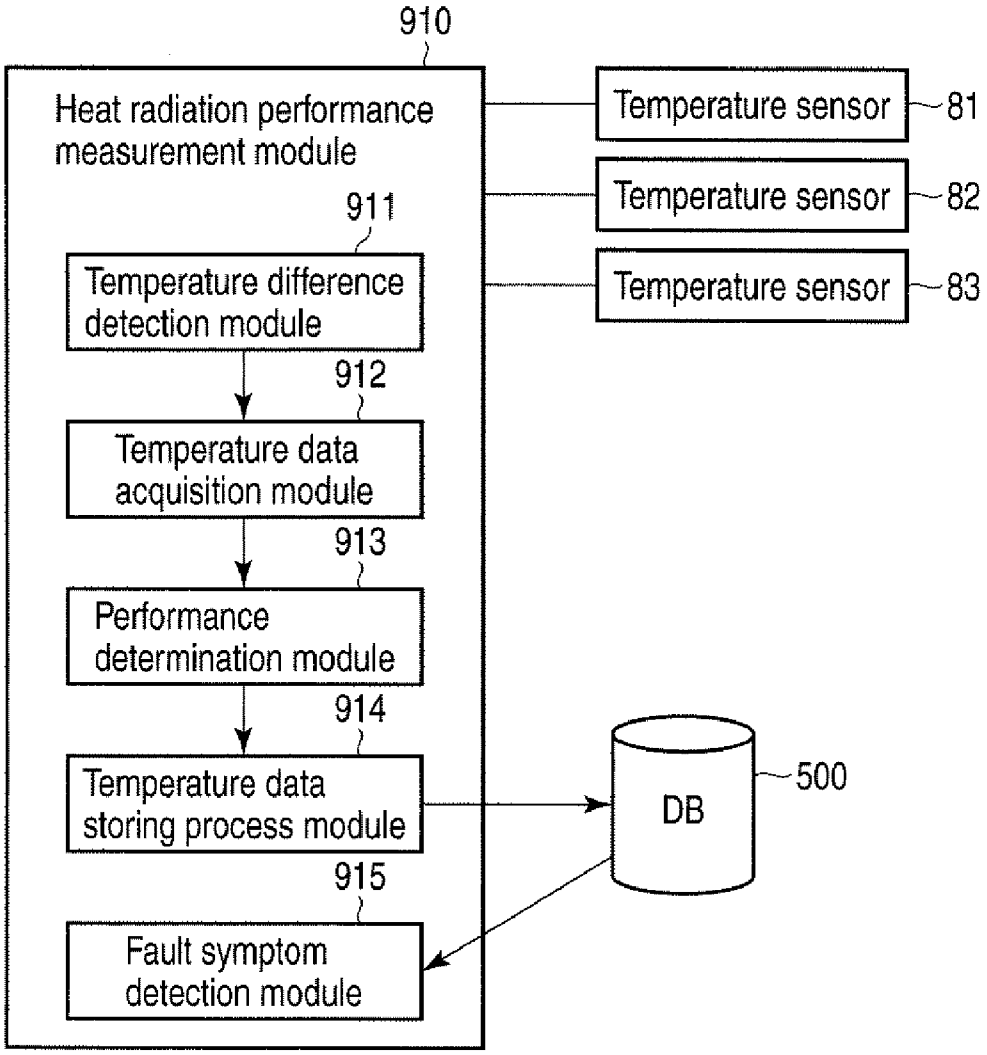

910
Heat radiation performance measurement module
911
Temperature difference detection module
912
Temperature data acquisition module
913
Performance determination module
914
Temperature data storing process module
915
Fault symptom detection module
Temperature sensor
81
Temperature sensor
82
Temperature sensor
83
DB
500

FIG. 21

INFORMATION PROCESSING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based upon and claims the benefit of priority from Japanese Patent Application No. 2008-171487, filed Jun. 30, 2008, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] 1. Field

[0003] One embodiment of the invention relates generally to an information processing apparatus such as a personal computer, and more particularly to an information processing apparatus including a heat radiation module.

[0004] 2. Description of the Related Art

[0005] In recent years, portable personal computers of various types, such as a laptop type and a notebook type, have been developed. This type of computer includes heating devices such as a CPU, a display controller, a hard disk drive and a bus bridge device.

[0006] As a cooling mechanism for cooling the heating devices, there is known a heat radiation module which makes use of, e.g. a fan and a heat radiation fin (heat sink).

[0007] Jpn. Pat. Appln. KOKAI Publication No. 2002-357317 discloses a power supply apparatus having a function of detecting clogging of an air inlet/outlet port. In this power supply apparatus, when a difference between an outside temperature and a temperature in the power supply apparatus exceeds a predetermined range, it is detected that abnormality has occurred at the air inlet/outlet port of the power supply apparatus, and a process of turning off the apparatus is executed.

[0008] In the meantime, the load of the information processing apparatus, such as a computer, varies greatly depending on the content of a process that is to be executed. In accordance with the variation of the load, the temperature in the vicinity of the heating device varies. For example, in the case where the load on the computer rises instantaneously, the heat, which surpasses the heat radiation performance of the heat radiation module, is produced from the heating device, and thereby the temperature in the vicinity of the heating device temporarily rises. Subsequently, the dissipation of the heat by the heat radiation module progresses and the temperature in the vicinity of the heating device gradually falls within a certain temperature range. In this manner, the temperature in the vicinity of the heating device varies in accordance with the variation of the load.

[0009] Thus, if the presence/absence of the decrease in performance of the heat radiation module is simply determined on the basis of only the result of comparison between the temperature outside the computer and the temperature within the computer, it would be possible that a temporary increase in load is erroneously determined as a decrease in performance of the heat radiation module.

[0010] In addition, in usual cases, in order to measure the performance of the heat radiation module, the user is required to perform an operation for starting a purpose-specific checking program for the performance measurement of the heat radiation module.

[0011] In this case, although the performance of the heat radiation module can be measured during a specific period in which the checking program is being executed, it is not possible to measure the performance of the heat radiation module in an ordinary operation state of the computer, in which the checking program is not executed. It is necessary, therefore, to realize a novel function for precisely detecting the performance of the heat radiation module.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012] A general architecture that implements the various feature of the invention will now be described with reference to the drawings. The drawings and the associated descriptions are provided to illustrate embodiments of the invention and not to limit the scope of the invention.

[0013] FIG. **1** is an exemplary perspective view showing a front-side external appearance of an information processing apparatus according to a first embodiment of the invention;

[0014] FIG. **2** is an exemplary block diagram for describing a cooling mechanism which is mounted in the information processing apparatus according to the first embodiment;

[0015] FIG. **3** is an exemplary block diagram showing the structure of a heat radiation performance measurement module which is provided in the information processing apparatus according to the first embodiment;

[0016] FIG. **4** is an exemplary view showing the relationship between the power consumption of the information processing apparatus according to the first embodiment, on the one hand, and the temperature of a heating device and the temperature within the casing, on the other hand;

[0017] FIG. **5** is an exemplary view showing the relationship between the power consumption of the information processing apparatus according to the first embodiment and the temperature of cooling air;

[0018] FIG. **6** is an exemplary block diagram showing the system configuration of the information processing apparatus according to the first embodiment;

[0019] FIG. **7** is an exemplary block diagram showing a structure example of a cooling mechanism which is applied to the system configuration shown in FIG. **6**;

[0020] FIG. **8** is an exemplary block diagram showing the relationship between hardware and software, which corresponds to the case in which parts of the functions of the heat radiation performance measurement module shown in FIG. **3** are realized by software;

[0021] FIG. **9** is an exemplary flow chart illustrating the procedure of a temperature difference detection process which is executed by the information processing apparatus according to the first embodiment;

[0022] FIG. **10** is an exemplary flow chart illustrating the procedure of a monitoring process which is executed by the information processing apparatus according to the first embodiment;

[0023] FIG. **11** is an exemplary view showing an example of the temperature variation of the heating device which is provided in the information processing apparatus according to the first embodiment;

[0024] FIG. **12** is an exemplary flow chart showing the procedure of a fan current measuring process which is executed by the information processing apparatus according to the first embodiment;

[0025] FIG. **13** is an exemplary flow chart showing the procedure of a fan current monitoring process which is executed by the information processing apparatus according to the first embodiment;

[0026] FIG. **14** shows an example of the arrangement of a cooling mechanism and first to third temperature sensors, which are mounted in an information processing apparatus according to a second embodiment of the invention;

[0027] FIG. **15** is an exemplary view for explaining variations of temperatures which are detected by the first and second temperature sensors shown in FIG. **14**;

[0028] FIG. **16** is an exemplary view for explaining variations of temperatures which are detected by the second and third temperature sensors shown in FIG. **14**;

[0029] FIG. **17** is an exemplary block diagram showing a structure example of a heat radiation performance measurement module which is used in the second embodiment;

[0030] FIG. **18** shows an example of the arrangement of a cooling mechanism and first to third temperature sensors, which are mounted in an information processing apparatus according to a third embodiment of the invention;

[0031] FIG. **19** is an exemplary view for explaining variation characteristics of temperatures which are detected by the first to third temperature sensors shown in FIG. **18**;

[0032] FIG. **20** is an exemplary view for explaining variation characteristics of temperatures which are detected by the first to third temperature sensors shown in FIG. **18**; and

[0033] FIG. **21** is an exemplary block diagram showing a structure example of a heat radiation performance measurement module which is used in the third embodiment.

DETAILED DESCRIPTION

[0034] Various embodiments according to the Invention will be described hereinafter with reference to the accompanying drawings. In general, according to one embodiment of the invention, there is provided an information processing apparatus comprising a housing, a printed circuit board provided in the housing, a heating device disposed on the printed circuit board, a heat radiation module provided in the housing, a first temperature sensor, a second temperature sensor, a temperature difference detection module, and a performance determination module. The heat radiation module is configured to exhaust heat of the heating device to outside. The first temperature sensor is configured to detect a temperature at a first position on the printed circuit board. The second temperature sensor is configured to detect a temperature at a second position on the printed circuit board, which is farther from the heating device than the first position. The temperature difference detection module is configured to detect a temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the first position detected by the first temperature sensor. The performance determination module is configured to be activated when the detected temperature difference exceeds a threshold value, to execute a monitoring process of monitoring the temperature difference between the temperature at the first position and the temperature at the second position during a predetermined period from a time point when the detected temperature difference exceeds the threshold value, and to determine, based on a result of the monitoring process, whether a performance of the heat radiation module has lowered or not.

First Embodiment

[0035] To begin with, referring to FIG. **1**, the structure of an information processing apparatus according to a first embodiment of the present invention is described. The information processing apparatus is realized, for example, as a battery-powerable portable notebook personal computer **10**.

[0036] FIG. **1** is a perspective view showing, from the front side, the computer **10** in the state in which a display unit of the computer **10** is opened.

[0037] The computer **10** comprises a housing **11** as a computer main body, and a display unit **12**. A display device that is composed of an LCD (Liquid Crystal Display) **17** is built in the display unit **12**. The display screen of the LCD **17** is positioned at an approximately central part of the display unit **12**.

[0038] The display unit **12** is supported on the housing **11** and is attached to the housing **11** such that the display unit **12** is freely rotatable between an open position where the top surface of the housing **11** is exposed and a closed position where the top surface of the housing **11** is covered by the display unit **12**. A printed circuit board is provided in the housing **11**. Various heating devices, such as a CPU, a display controller, a hard disk drive and a bus bridge device, are mounted on the printed circuit board.

[0039] A keyboard **13**, a power button **14** for powering on/off the computer **10**, an input operation panel **15** and a touch pad **16** are disposed on the top surface of the housing **11**.

[0040] The input operation panel **15** is an input device which inputs an event corresponding to a pressed button. The input operation panel **15** has a plurality of buttons for activating a plurality of functions. The buttons include buttons **15**A and **15**B for activating specific application programs.

[0041] FIG. **2** shows an example of a cooling mechanism which is provided in the housing **11**. As shown in FIG. **2**, a heat radiation module **20**, a heating device **21**, and temperature sensors **31**, **32** and **33** are provided in the housing **11**.

[0042] The heating device **21** is a device such as a central processing unit (CPU), a display controller, a hard disk drive or a bus bridge device. The heating device **21** is disposed on a printed circuit board (PCB) **111** which is provided in the housing **11**. The printed circuit board **111** is a so-called motherboard on which various electronic components constituting the computer **10** are mounted.

[0043] The heat radiation module **20** radiates the heat of the heating device **21**, which is an object of cooling, to the outside.

[0044] The heat radiation module **20** is composed of, for instance, a fan **22** and a heat radiation fin (also referred to as "heat sink") **23**. An air outlet port (air outlet opening) **18** is provided in one side wall of the housing **11**. In addition, an air inlet port (air inlet opening) **19** is provided, for example, in another side wall of the housing **11**. The heat radiation fin **23** is provided within the housing **11** at such a position that the heat radiation fin **23** is opposed to the air outlet port **18**. Specifically, the heat radiation fin **23** is provided near the air outlet port **18** in such a fashion that the heat radiation fin **23** is opposed to the air outlet port **18**. The heat radiation fin **23** is thermally connected to the heating device **21** via a heat-receiving module, etc. To be more specific, the heat radiation fin **23** is thermally connected to the heating device **21** via a heat pipe **24** and a heat-receiving module **25**.

[0045] The fan **22** is a cooling fan for cooling the heat radiation fin **23**. The fan **22** is disposed near the heat radiation fin **23**. The fan **22** cools by air the heat radiation fin **23** that is thermally connected to the heating device **21**, thereby exhausting the heat of the heating device **21** to the outside via the air outlet port **18**.

[0046] The temperature sensors **31** to **33** are provided on the printed circuit board **111**. Each of the temperature sensors **31** to **33** is composed of, for instance, a thermistor or a dedicated temperature sensor IC, which is attached on the printed circuit board **111**.

[0047] The temperature sensor **31** is used in order to detect the ambient temperature of the heating device **21**. Specifically, the temperature sensor **31** functions as a first temperature sensor which detects the temperature at a first position on the printed circuit board **111**, which is close to the heating device **21** (i.e. the board temperature near the heating device **21**). The temperature sensor **31** is provided at the first position on the printed circuit board **111**, which is close to the heating device **21**, and is used in order to monitor the effect of the board temperature due to the heat production of the heating device **21**. In case abnormality has occurred in the heat radiation module **20**, the amount of heat that is conducted from the heating device **21** to the heat radiation module **20** decreases. As a result, the heat of the heating device **21** transfers to the printed circuit board **111**, and the temperature at the first position on the printed circuit board **111**, which is close to the heating device **21**, rises. The temperature at the first position on the printed circuit board **111** is detected by the temperature sensor **31**. In short, the temperature sensor **31** functions as the sensor for detecting the temperature rise due to abnormality of the heat radiation module **20**.

[0048] The temperature sensor **32** functions as a second temperature sensor which detects the temperature at a second position on the printed circuit board **111**, which is farther from the heating device **21** than the first position (i.e. the intra-housing temperature). Specifically, the temperature sensor **32** is disposed at an end portion on the board **111**, which is hardly affected by the heat that is produced by the heating device **21**. The heating device **21** is disposed at a position which is shifted from the central position toward one side wall within the housing **11**. In this case, the temperature sensor **32** may be disposed at a position which is shifted toward another side wall that is opposed to said one side wall. As shown in FIG. **2**, in the case where the heating device **21** is disposed at one corner portion within the housing **11**, the temperature sensor **32** may be disposed at another corner portion which is diagonally away from said one corner portion.

[0049] The temperature at the second position on the printed circuit board **111**, which is detected by the temperature sensor **32**, is used as a reference temperature for evaluating the temperature at the first position on the printed circuit board **111** (the board temperature near the heating device **21**) which is detected by the temperature sensor **31**.

[0050] The temperature sensor **33** is provided at a third position on the board **111**, which is located between the air inlet port **19** provided in the housing **11** and the heat radiation module **20**. The temperature sensor **33** is used as a third temperature sensor which detects the temperature at the third position on the board **111**, that is, the temperature of the air (cooling air) flowing from the air inlet port **19** toward the heat radiation module **20**. For example, as shown in FIG. **2**, the temperature sensor **33** is provided at a position on the opposite side to the heating device **21**, with the heat radiation module **20** being interposed between the temperature sensor **33** and the heating device **21**. Thereby, the temperature sensor **33** can precisely detect the temperature of the incoming air (cooling air) from the outside, without being influenced by the heat of the heating device **21**.

[0051] Next, referring to FIG. **3**, a description is given of the structure of a heat radiation performance measurement module **41** which is provided in the computer **10**.

[0052] The heat radiation performance measurement module **41** is provided within the housing **11**. The heat radiation performance measurement module **41** measures the performance of the heat radiation module **20** by using the temperature sensors **31**, **32** and **33**, or by using only the temperature sensors **31** and **32**.

[0053] The heat radiation performance measurement module **41** includes a temperature difference detection module **411**, a temperature data acquisition module **412**, a performance determination module **413**, a temperature data storing process module **414** and a fault symptom detection module **415**.

[0054] The temperature difference detection module **411** detects a temperature difference (T**1**−Tref) which is obtained by subtracting the temperature (Tref), which is detected by the temperature sensor **32**, from the temperature (T**1**) which is detected by the temperature sensor **31**.

[0055] The performance determination module **413** is activated when the temperature difference (T**1**−Tref), which is detected by the temperature difference detection module **411**, exceeds a certain specific threshold value TH**1**. The performance determination module **413** continuously executes, during a predetermined time period from the time point when the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**, a monitoring process of monitoring the temperature difference (T**1**−Tref) between the temperature (T**1**) that is detected by the temperature sensor **31** and the temperature (Tref) that is detected by the temperature sensor **32**. On the basis of the result of this monitoring process, the performance determination module **413** determines whether the performance of the heat radiation module **20** has lowered or not. In the monitoring process, it may be possible to monitor not only the temperature difference (T**1**−Tref) between the temperature (T**1**) that is detected by the temperature sensor **31** and the temperature (Tref) that is detected by the temperature sensor **32**, but also a temperature difference (T**2**−Tref) between the temperature (T**2**) of the cooling air and the temperature (Tref) in the housing **11**. Thereby, it becomes possible to detect not only the presence/absence of the decrease in performance of the heat radiation module **20**, but also the occurrence of a fault, such as clogging, of the air inlet port **19**.

[0056] In the monitoring process, the performance determination module **413** executes an acquisition process of acquiring, via the temperature data acquisition module **412**, a pair of a first temperature sample value that is indicative of the board temperature near the heating device **21**, which is detected by the temperature sensor **31**, and a second temperature sample value that is indicative of the intra-housing temperature which is detected by the temperature sensor **32**. This acquisition process is repeatedly executed at predetermined time intervals (e.g. in every 3 seconds) during a predetermined time period. On the basis of the pairs obtained during the predetermined time period, the performance determination module **413** determines whether the performance of the heat radiation module **20** has lowered or not. In this case, it can be determined whether the performance of the heat radiation module **20** has lowered or not, on the basis of the number of pairs in which a difference that is obtained by subtracting the second temperature sample value from the first temperature sample value exceeds a reference value K.

[0057] Specifically, the performance determination module **413** calculates a difference (T**1**−Tref) between the first temperature sample value (T**1**) and the second temperature sample value (Tref) with respect to each of the pairs acquired during the predetermined time period, and calculates the number of pairs which meet the condition that the difference (T**1**−Tref) exceeds the reference value K. In the case where the number of pairs, which meet the condition that the difference (T**1**−Tref) exceeds the reference value K, is greater than a reference number in the pairs acquired during the predetermined time period, the performance determination unit **413** determines that the performance of the heat radiation module **20** has lowered. As the reference value K, a value higher than the threshold value TH**1** can be used.

[0058] In the monitoring process, the above-described acquisition process may be executed on condition that the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**. In this case, the performance determination module **413** determines, at a sampling timing of every three seconds, whether the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**. In the case where the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**, the performance determination module **413** executes the acquisition process of acquiring a pair of the first temperature sample value that is indicative of the board temperature near the heating device **21**, which is detected by the temperature sensor **31**, and the second temperature sample value that is indicative of the intra-housing temperature which is detected by the temperature sensor **32**. On the other hand, in the case where the temperature difference (T**1**−Tref) does not exceed the threshold value TH**1**, the performance determination module **413** skips the execution of the acquisition process, and stands by until the coming of the next sampling timing. The performance determination module **413** determines whether the performance of the heat radiation module **20** has lowered or not, according to whether a predetermined number of pairs have been acquired during a predetermined time period. For example, if a predetermined number of pairs have been acquired during a predetermined time period, the lowering of the performance of the heat radiation module **20** is determined.

[0059] Instead of determining the presence/absence of the lowering of the performance of the heat radiation module **20** according to whether a predetermined number of pairs have been acquired during a predetermined time period, it is possible to further analyze the predetermined number of pairs that have been acquired during the predetermined time period. Specifically, in the case where a predetermined number of pairs have been acquired during a predetermined time period, the performance determination module **413** calculates the number of pairs included in the predetermined number of pairs, which meet the condition that the difference (T**1**−Tref) that is obtained by subtracting the second temperature sample value (Tref) from the first temperature sample value (T**1**) exceeds the reference value K higher than the threshold value TH**1**. If the calculated number of pairs exceeds a specified reference number, the performance determination module **413** determines that the performance of the heat radiation module **20** has lowered.

[0060] The monitoring process by the performance determination module **413** is executed each time the temperature detection module **411** detects that the temperature difference (T**1**−Tref) exceeds the threshold value TH**1** during the normal operation of the computer **10**.

[0061] The temperature data storing process module **414** stores pairs of first temperature sample values and second temperature sample values, which are acquired by the performance determination module **413** each time the monitoring process is executed, in a database **500** as one set of temperature data. The database **500** is a storage device which is provided in the computer **10**. As the number of days, which have passed since the user purchased the computer **10**, increases, the number of sets of temperature data accumulated in the database **500** increases. After a plurality of sets of temperature data are stored in the database **500**, the fault symptom detection module **415** reads out these sets of temperature data from the database **500**. Then, the fault symptom detection module **415** analyzes the read-out plural sets of temperature data, and detects a symptom relating to a fault of the heat radiation module **20**, from the tendency of temperature variation of the heating device **21**, which is indicated by the plural sets of temperature data. For example, the fault symptom detection module **415** comprehends the tendency of the lowering of the performance of the heat radiation module **20**, from the plural sets of temperature data accumulated in the database **500**, and detects the presence/absence of the symptom of a fault of the heat radiation module **20**. In this case, it is possible to predict when in the future a fault may possibly occur in the heat radiation module **20**.

[0062] FIG. **4** shows the relationship between the power consumption of the computer **10**, on the one hand, and the board temperature near the heating device and the intra-housing temperature, on the other hand.

[0063] As the load of the heating device **21** becomes greater and the power consumption thereof increases, the power consumption of the computer **10** increases accordingly. Specifically, as the load of the heating device **21** becomes greater and the power consumption thereof increases, the detection temperature of the temperature sensor **31** (i.e. the board temperature near the heating device) increases accordingly. On the other hand, the detection temperature of the temperature sensor **32** (i.e. the intra-housing temperature) hardly increases even if the power consumption of the heating device **21** increases. In FIG. **4**, a solid line L**1** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **31** in the case where the heat radiation module **20** normally operates. A broken line L**2** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **31** in the case where the performance of the heat radiation module **20** has lowered. In the case where the performance of the heat radiation module **20** has lowered (for example, in the case where the performance of the fan has lowered, or a problem has occurred in the heat pipe), the inclination of the temperature rise increases, as indicated by the broken line L**2**. A solid line L**3** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **32**.

[0064] FIG. **5** shows the relationship between the power consumption of the computer **10** and the temperature of cooling air.

[0065] At a normal time, the detection temperature of the temperature sensor **33** (the temperature of the cooling air) hardly varies even if the power consumption varies, as indicated by a solid line L**5**. However, if the air inlet port **19** is closed due to accumulation of dust or clogging of the air inlet portion **19**, the air in the housing **11** is not properly exhausted

and hence the detection temperature of the temperature sensor **33** rises, as indicated by a broken line L**6**.

[0066] Thus, not only when the temperature difference (T**1**−Tref) between the detection temperature (T**1**) of the temperature sensor **31** and the detection temperature (Tref) of the temperature sensor **32** has exceeded the threshold TH**1**, but also when the temperature difference (T**2**−Tref) between the detection temperature (T**2**) of the temperature sensor **33** and the detection temperature (Tref) of the temperature sensor **32** has exceeded the threshold TH**2**, the above-described monitoring process may be started with this timing being a trigger.

[0067] Next, referring to FIG. **6**, the system configuration of the computer **10** is described.

[0068] The computer **10** comprises a CPU **111**, a north bridge **112**, a main memory **113**, a display controller **114**, a south bridge **115**, a hard disk drive (HDD) **116**, a network controller **117**, a flash BIOS-ROM **118**, an embedded controller/keyboard controller IC (EC/KBC) **119**, and a power supply controller **120**.

[0069] The CPU **111** is a processor which controls the operation of the respective components of the computer **10**. The CPU **111** executes an operating system and various application programs/utility programs, which are loaded from the HOD **116** into the main memory **113**. In addition, the CPU **111** executes a system BIOS (Basic Input/Output System) that is stored in the flash BIOS-ROM **118**. The system BIOS is a program for hardware control.

[0070] The north bridge **112** is a bridge device which connects a local bus of the CPU **111** and the south bridge **115**. The north bridge **112** has a function of executing communication with the display controller **114** via, e.g. an AGP (Accelerated Graphics Port) bus. In addition, the north bridge **112** includes a memory controller which access-controls the main memory **113**.

[0071] The display controller **114** controls the LCD **17** which is used as a display monitor of the computer **10**. The display controller **114** has a rendering arithmetic function, and the display controller **114** functions as a graphics accelerator. The south bridge **115** is connected to a PCI (Peripheral Component Interconnect) bus and to an LPC (Low Pin Count) bus.

[0072] The embedded controller/keyboard controller IC (EC/KBC) **119** is a 1-chip microcomputer in which an embedded controller for power management and a keyboard controller for controlling the keyboard (KB) **13** and touch pad **16** are integrated. The embedded controller/keyboard controller IC **119** cooperates with the power supply controller **120** to power on/off the computer **10** in response to the user's operation of the power button switch **14**. The power supply controller **120** generates system power, which is to be supplied to the respective components of the computer **10**, by using a battery **121** or an external power which is supplied via an AC adapter **122**.

[0073] In the system of FIG. **6**, for instance, the CPU **111**, display controller **114**, north bridge **112** or HDD **116** is heating device.

[0074] Next, referring to FIG. **7**, an example of a cooling mechanism, which is applied to the system of FIG. **6**, is described.

[0075] The above-described heat radiation performance measurement module **41** may be provided, for example, in the EC/KBC **119**. In the EC/KBC **119**, a heat radiation fin abnormality detection module **61** and a fan control module **62** are also provided.

[0076] A resistor **221** and an operational amplifier **222** function as a power supply current detection module **220** which detects a power supply current (fan current) that is supplied to the fan **22**. If clogging occurs in the heat radiation fin **23**, air does not flow and the resistance of the fan **22** decreases. As a result, if clogging occurs, the value of the power supply current corresponding to a certain fan rotation number decreases. The value of the power supply current, which is detected by the power supply current detection module **220**, is supplied to the heat radiation fin abnormality detection module **61** via the power supply controller **120**.

[0077] The heat radiation fin abnormality detection module **61** detects clogging of the heat radiation fin **23**, on the basis of the relationship between the present rotation number (present rotation speed) of the fan **22** and the value of the power supply current which is detected by the power supply current detection module **220**. The heat radiation fin abnormality detection module **61** acquires the rotation number of the fan **22**, for example, from the fan control module **62**. The fan control module **62** controls the rotation number of the fan **22**. The control of the rotation number of the fan **22** is executed, for example, in accordance with the temperature that is detected by the temperature sensor **31**. As the temperature that is detected by the temperature sensor **31** becomes higher, the rotation number of the fan **22** is increased. The fan control module **62** may also detect the rotation number of the fan **22** in accordance with a rotation number signal which is output from the fan **22**. The rotation number signal is, for instance, a pulse signal. Two pulse signals per rotation of the fan **22**, for example, are output as the rotation number signal from the fan **22**.

[0078] Parts of the functions of the above-described heat radiation measurement module **41** may be realized by a program which is executed by the CPU **111**.

[0079] FIG. **8** shows the relationship between hardware and software, which corresponds to the case in which parts of the functions of the heat radiation performance measurement module **41** are realized by a program.

[0080] The power supply current value of the fan **22** is sent from the power supply controller **120** to the EC/KBC **119**. The EC/KBC **119** is provided with, for example, the temperature difference detection module **411** shown in FIG. **3**. When the temperature difference (T**1**−Tref) exceeds the threshold value, the EC/KBC **119** generates an event for starting the monitoring process. This event is delivered to a heat radiation module measurement application program **600** via the BIOS and OS. This heat radiation module measurement application program **600** has functions corresponding to the temperature data acquisition module **412**, performance determination module **413**, temperature data storing process module **414** and fault symptom detection module **415**, which are shown in FIG. **3**.

[0081] Next, referring to a flow chart of FIG. **9**, a description is given of the procedure of a temperature difference detection process which is executed by the EC/KBC **119**.

[0082] The temperature difference detection module **411** in the EC/KBC **119** executes the following process during the time period in which the computer **10** is in the power-on state. Specifically, the EC/KBC **119** executes a temperature measurement process for acquiring detection temperatures from the temperature sensors **31**, **32** and **33** at predetermined time intervals (block S**11**, S**12**). The EC/KBC **119** calculates a temperature difference (T**1**−Tref) which is obtained by subtracting the temperature Tref, which is detected by the tem-

perature sensor **32**, from the temperature T**1** which is detected by the temperature sensor **31**. The EC/KBC **119** determines whether the temperature difference (T**1**−Tref) exceeds a threshold TH**1** (block S**13**).

[0083] If the temperature difference (T**1**−Tref) exceeds the threshold TH**1** (YES in block S**13**), the EC/KBC **119** generates an event for instructing the start of the monitoring process, thereby instructing the heat radiation module measurement application program **600** to start the monitoring process (block S**14**). In block S**14**, for example, the EC/KBC **119** generates an interrupt signal to the CPU **111**, thereby reporting the occurrence of the event to the heat radiation module measurement application program **600** via the BIOS and OS.

[0084] In block S**13**, the EC/KBC **119** may calculate a temperature difference (T**2**−Tref) which is obtained by subtracting the temperature Tref, which is detected by the temperature sensor **32**, from the temperature T**2** which is detected by the temperature sensor **33**, and may determine whether the temperature difference (T**2**−Tref) exceeds a certain threshold TH**2**. Also in the case where the temperature difference (T**2**−Tref) exceeds the threshold TH**2**, the EC/KBC **119** may generate an event for instructing the start of the monitoring process, thereby instructing the heat radiation module measurement application program **600** to start the monitoring process (block S**14**).

[0085] Next, referring to a flow chart of FIG. **10**, a description is given of the procedure of the monitoring process which is executed by the heat radiation module measurement application program **600**.

[0086] The heat radiation module measurement application program **600** starts the following process, upon receiving the above-described event. At first, the outline of the monitoring process is explained.

[0087] Upon receiving the event from the EC/KBC **119**, the heat radiation module measurement application program **600** reads from the EC/KBC **119** a pair (sample data) including a first temperature sample value that is indicative of the temperature which is detected by the temperature sensor **31**, and a second temperature sample value that is indicative of the temperature which is detected by the temperature sensor **32**. In the meantime, not only the pair of the first temperature sample value and second temperature sample value, but also a third temperature sample value that is indicative of the temperature detected by the temperature sensor **33** may be read together. In the description below, exemplification is made of the case in which the pair of the first temperature sample value and second temperature sample value is read as sample data.

[0088] This sample data read process is repeatedly executed at predetermined time intervals (e.g. in every 3 seconds). The sample data read process is repeated until 40 sample data (40 pairs of sample values) are collected. Thus, during the period (monitoring period) of at least 120 seconds, the monitoring process is continued. If 40 sample data are collected, the heat radiation module measurement application program **600** determines whether the performance of the heat radiation module **20** has lowered, on the basis of the 40 sample data.

[0089] A concrete example of the monitoring process is described below.

[0090] Under the control of the heat radiation module measurement application program **600**, the CPU **111** executes the following process.

[0091] To start with, the CPU **111** initializes the value of the counter, which counts the number of sample data that are acquired, to 1 (block S**21**). Then, the CPU **111** reads the first temperature sample value (T**1**) and second temperature sample value (Tref) from the EC/KBC **119** (block S**22**), and determines whether the temperature difference (T**1**−Tref) between the first temperature sample value (T**1**) and second temperature sample value (Tref) is greater than the threshold value TH**1** (block S**23**).

[0092] If the temperature difference (T**1**−Tref) is greater than the threshold value TH**1** (YES in block S**23**), the CPU **111** executes a process of acquiring the first temperature sample value (T**1**) and second temperature sample value (Tref), which have been read, as valid sample data (block S**24**). In block S**24**, the CPU **111** stores the first temperature sample value (TI) and second temperature sample value (Tref) in the memory **113**, and increments the value of the counter by +1.

[0093] It the temperature difference (T**1**−Tref) is not greater than the threshold value TH**1** (NO in block S**23**), the CPU **111** skips the acquisition process of block S**24**.

[0094] After executing the acquisition process of block S**24**, the CPU **111** determines whether the value of the counter exceeds 40 (block S**25**). If the value of the counter is not greater than 40 (NO in block S**25**) or if the temperature difference (T**1**−Tref) is not greater than the threshold value TH**1** (NO in block S**23**), the CPU **111** determines whether a predetermined time-out period (e.g. 5 minutes) has passed since the reception of the event (block S**29**). If the predetermined time-out period has not passed since the reception of the event (NO in block **29**), the CPU **111** stands by until a time point when the next sampling timing will come, that is, until three seconds will have passed since the previous temperature read (block S**30**). When three seconds have passed since the previous temperature read (YES in block S**30**), the CPU **111** resumes the process from block S**22**.

[0095] If the value of the counter exceeds 40 before the predetermined time-out period has passed since the reception of the event, that is, if 40 sample data have been acquired (YES in block S**25**), the CPU **111** determines whether the performance of the heat radiation module **20** has lowered or not, on the basis of the 40 sample data (i.e. 40 pairs of the first temperature sample value T**1** and second temperature sample value Tref) (block S**26**).

[0096] Each of the 40 sample data is data that is acquired at the time when the load of the computer is high (i.e. in the period in which T**1**−Tref>TH**1**), and is used as data for examining by what degree the temperature of the heating device **21** exceeds the temperature of the housing **11**.

[0097] Even if the performance of the heat radiation module **20** has lowered, the influence due to the lowering of the performance is hardly observed at a time of low load. In the present embodiment, since the performance of the heat radiation module **20** is evaluated by using the sample data that is acquired at a time of high load (i.e. in the period in which T**1**−Tref>TH**1**), the performance of the heat radiation module **20** can correctly be evaluated.

[0098] In block S**26**, the CPU **111** calculates, for example, the temperature difference (T**1**−Tref) with respect to all the pairs, and determines whether the temperature difference (T**1**−Tref) is greater than the reference value K. The CPU **111** determines the presence/absence of the lowering of performance of the heat radiation module **20**, on the basis of, e.g. the frequency of occurrence of pairs in which the temperature

difference (T1−Tref) is greater than the reference value K. Specifically, if the number of those pairs included in the 40 pairs, which meet the condition that the temperature difference (T1−Tref) exceeds the reference value K, exceeds a certain reference number, the CPU **111** determines that some fault occurs in the heat radiation module **20** and the performance of the heat radiation module **20** has lowered.

[0099] If the CPU **111** detects the lowering in performance of the heat radiation module **20** (NG in block S**26**), the CPU **111** executes a process of informing the user of the lowering in performance of the heat radiation module **20** (block S**27**). In block S**27**, the CPU **111** displays a message screen for informing the user of the lowering in performance of the heat radiation module **20**. Specifically, the CPU executes, for example, 1) a process of displaying on the display screen of the LCD **17** a message screen which indicates that the maintenance of the heat radiation module **20** is necessary, 2) a process of displaying a message screen for guiding the procedure of maintenance of the heat radiation module **20** to the user, and 3) a process of displaying a message screen which prompts the user to start a purpose-specific checking program for the performance measurement of the heat radiation module. Besides, the CPU **111** may calculate the ratio of the current heat radiation performance to the heat radiation performance at the normal time of the heat radiation module **20**, and may display the calculated ratio on the message screen.

[0100] Subsequently, the CPU **111** stands by for the user's operation on the message screen (block S**28**), and executes, in accordance with the user's operation, a process of closing the message screen, a process of guiding the maintenance procedure, or a process of starting the purpose-specific checking program.

[0101] As indicated by a broken line in FIG. **10**, it may be determined that the performance of the heat radiation module **20** has lowered, on condition that the value of the counter becomes greater than 40 before the predetermined time-out period has passed since the reception of the event.

[0102] The description of the flow chart of FIG. **10** is directed to the case in which the pairs of the first temperature sample value and second temperature sample value are acquired as sample data. Similarly, three temperature sample values, namely, the first temperature sample value, second temperature sample value and third temperature sample value, may be acquired as sample data. The use of the third temperature sample value also makes it possible to detect the occurrence of abnormality, such as clogging, of the air inlet port.

[0103] If the aim is to detect only the abnormality such as clogging of the air inlet port, only pairs of the second temperature sample value and third temperature sample values may be acquired. In this case, the EC/KBC **119** generates an event when the temperature difference (T**2**−Tref) between the third temperature sample value (T**2**) and the second temperature sample value (Tref) has exceeded the threshold value TH**2**. In response to the occurrence of this event, the heat radiation module measurement application program **600** starts the monitoring process In the monitoring process, the heat radiation module measurement application program **600** repeatedly executes, at intervals of three seconds, (1) a process of determines whether the temperature difference (T**2**−Tref) is greater than the threshold value TH**2** and (2) a process of acquiring pairs of the third temperature sample value (T**2**) and the second temperature sample value (Tref) if the temperature difference (T**2**−Tref) is greater than the threshold value TH**2**. If 40 sample data are acquired during the time-out period, the heat radiation module measurement application program **600** determines the presence/absence of the clogging of the air inlet port, on the basis of the 40 sample data. As the determining method, use may be made of such a method as to determine the presence/absence of the clogging of the air inlet port in accordance with, e.g. the frequency of occurrence of pairs in which the temperature difference (T**2**−Tref) is greater than the reference value L. Besides, it may be determined that the air inlet port is clogged, on condition that 40 sample data are obtained before the predetermined time-out period has passed since the reception of the event.

[0104] FIG. **11** shows an example of the temperature variation of the heating device **21** at a time when a load variation occurs.

[0105] If the load of the heating device **21** sharply increases, the detection temperature of the temperature sensor **31** (the board temperature in the vicinity of the heating device **21**) sharply increases accordingly. When the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**, the heat radiation module measurement application program **600** starts the monitoring process in response to the event from the EC/KBC **119**.

[0106] In the case where the heat radiation module **20** normally operates, high-temperature air is exhausted to the outside by the function of the heat radiation module **20**. Thus, the detection temperature of the temperature sensor **31** (the board temperature near the heating device **21**) lowers and falls within a steady temperature range.

[0107] As described above, even if the performance of the heat radiation module **20** is normal, there is a case in which the temperature difference (T**1**−Tref) temporarily exceeds the threshold value TH**1** due to a variation in load of the heating device **21**.

[0108] In the case where the performance of the heat radiation module **20** lowers, a great deal of time is needed to exhaust high-temperature air to the outside, owing to the deficiency of the heat radiation performance of the heat radiation module **20**. Hence, once the temperature difference (T**1**−Tref) exceeds the threshold value TH**1** due to the increase in load of the heating device **21**, the detection temperature of the temperature sensor **31** (the temperature of the heating device **21**) does not easily lower, as indicated by a broken line in FIG. **11**.

[0109] In the present embodiment, the temperature difference (T**1**−Tref) is continuously monitored during the predetermined period from the time point when the temperature difference (T**1**−Tref) has exceeded the threshold value TH**1**. Therefore, such a temperature variation, that the temperature difference (T**1**−Tref) temporarily exceeds the threshold value TH**1**, can be prevented from being erroneously determined as the lowering of the performance of the heat radiation module **20**.

[0110] In the computer, the variation of the load of the heating device **21** occurs frequently. Thus, such a phenomenon may successively occur that the temperature difference (T**1**−Tref) temporarily exceeds the threshold value TH**1**, despite the performance of the heat radiation module **20** being normal.

[0111] In the present embodiment, the performance of the heat radiation module **20** is determined on the basis of the number of pairs in which the temperature difference (T**1**−Tref) exceeds the reference value K (K>TH**1**). Therefore, even if such a phenomenon successively occurs that the tem-

perature difference (T1−Tref) temporarily exceeds the threshold value TH1, it is possible to prevent this phenomenon from being erroneously determined as the lowering of the performance of the heat radiation module **20**.

[0112] Next, referring to a flow chart of FIG. **12**, a description is given of the procedure of a fan current measuring process which is executed by the EC/KBC **119**.

[0113] The EC/KBC **119** executes the fan current measuring process as illustrated in FIG. **12**, in parallel with the temperature difference detection process illustrated in FIG. **9**.

[0114] The heat radiation fin abnormality detection module **61** within the EC/KBC **119** executes the following process during the power-on state of the computer **10**. Specifically, the EC/KBC **119** executes, at predetermined time intervals, a process of acquiring a fan current value which is detected by the power supply current detection module **220**, and a rotation number of the fan **22** (block S**41**, S**42**). The EC/KBC **119** determines whether the fan current value, which is detected by the power supply current detection module **220**, is smaller than a predetermined threshold value (block S**43**). As this threshold value, use may be made of, for example, a value corresponding to the present rotation number of the fan **22**.

[0115] If the fan current value is smaller than the predetermined threshold value (YES in block S**43**), the EC/KBC **119** generates an event for instructing the start of the monitoring process, and instructs the heat radiation module measurement application program **600** to start the monitoring process (block S**44**). In block S**44**, for example, the EC/KBC **119** generates an interrupt signal to the CPU **111**, thereby reporting the occurrence of the event (hereinafter referred to as "event #**2**") to the heat radiation module measurement application program **600** via the BIOS and OS.

[0116] Next, referring to a flow chart of FIG. **13**, a description is given of the procedure of a fan current monitoring process which is executed by the heat radiation module measurement application program **600**.

[0117] The heat radiation module measurement application program **600** starts the following process, upon receiving the above-described event #**2**.

[0118] To start with, the CPU **111** initializes to 1 the value of the counter for counting the number of sample data that are acquired (block S**51**). Then, the heat radiation module measurement application program **600** reads the fan current value from the EC/KBC **119** (block S**52**), and determines whether the fan current value is smaller than the threshold value (block S**53**).

[0119] If the fan current value is smaller than the threshold value (YES in block S**53**), the CPU **111** executes a process of acquiring the fan current value, which has been read, as valid sample data (block S**54**). In block S**54**, the CPU **111** stores the sample data (fan current value) in the memory **113**, and increments the value of the counter by +1.

[0120] If the fan current value is not smaller than the threshold value (NO in block S**53**), the CPU **111** skips the acquisition process of block S**54**.

[0121] After executing the acquisition process of block S**54**, the CPU **111** determines whether the value of the counter exceeds 40 (block S**55**). If the value of the counter is not greater than 40 (NO in block S**55**) or if the fan current value is not smaller than the threshold value (NO in block S**53**), the CPU **111** determines whether a predetermined time-out period (e.g. 5 minutes) has passed since the reception of the event #**2** (block S**59**). If the predetermined time-out period has not passed since the reception of the event #**2** (NO in block S**59**), the CPU **111** stands by until a time point when the next sampling timing will come, that is, until three seconds will have passed since the previous fan current read (block S**60**). When three seconds have passed since the previous fan current read (YES in block S**60**), the CPU **111** resumes the process from block S**52**.

[0122] If the value of the counter exceeds 40 before the predetermined time-out period has passed since the reception of the event #**2**, that is, if 40 sample data have been acquired (YES in block S**55**), the CPU **111** determines whether clogging occurs in the heat radiation fin **23**, on the basis of the 40 sample data (block S**56**).

[0123] In block S**56**, the CPU **111** determines whether clogging occurs in the heat radiation fin **23**, on the basis of, e.g. the frequency of occurrence of sample data in which the fan current is smaller than a specified reference value.

[0124] Specifically, if the number of those sample data included in the 40 sample data, in which the fan current is smaller than the reference value, exceeds a certain reference number, the CPU **111** determines that clogging occurs in the heat radiation fin **23**.

[0125] If the CPU **111** detects the clogging of the heat radiation fin **23** (NG in block S**56**), the CPU **111** executes a process of informing the user of the clogging of the heat radiation fin **23** (block S**57**). In block S**57**, the CPU **111** displays a message screen for informing the user of the clogging of the heat radiation fin **23**. Specifically, the CPU executes, for example, 1) a process of displaying on the display screen of the LCD **17** a message screen which indicates that the maintenance of the heat radiation fin **23** is necessary, 2) a process of displaying a message screen for guiding the procedure of maintenance of the heat radiation fin **23** to the user, and 3) a process of displaying a message screen which prompts the user to start a purpose-specific checking program for the performance measurement of the heat radiation module.

[0126] Subsequently, the CPU **111** stands by for the user's operation on the message screen (block S**58**), and executes, in accordance with the user's operation, a process of closing the message screen, a process of guiding the maintenance procedure, or a process of starting the purpose-specific checking program.

[0127] As indicated by a broken line in FIG. **13**, it may be determined that clogging has occurred in the heat radiation fin **23**, on condition that the value of the counter becomes greater than 40 before the predetermined time-out period has passed since the reception of the event #**2**.

[0128] As has been described above, in the present first embodiment, by using as a trigger the occurrence of the event that the temperature difference between the temperature of the heating device and the intra-housing temperature exceeds the threshold value, the process of monitoring the temperature difference between the temperature of the heating device and the intra-housing temperature is executed continuously during the predetermined time period. By this monitoring process, a temporary increase of the load can be prevented from being erroneously determined as the lowering of the performance of the heat radiation module.

Second Embodiment

[0129] Next, another example of arrangement of a plurality of temperature sensors, which are applied to the computer **10**, will be described as a second embodiment of the present

invention. In the description below, only parts different from the first embodiment are mainly described.

[0130] FIG. **14** shows the positional relationship between a cooling mechanism which is provided in the housing **11**, and a plurality of temperature sensors. As shown in FIG. **14**, a heat radiation module **20**, a heating device **21**, and temperature sensors **71**, **72** and **73** are provided in the housing **11**.

[0131] An air outlet port **18** is provided in one side wall of the housing **11**. In addition, an air inlet port **19** is provided, for example, in another side wall of the housing **11**.

[0132] The temperature sensors **71** to **73** are provided on the printed circuit board **111**. Each of the temperature sensors **71** to **73** is composed of, for instance, a thermistor or a dedicated temperature sensor IC, which is attached on the printed circuit board **111**.

[0133] The temperature sensor **71**, like the above-described temperature sensor **31**, functions as a sensor for detecting a temperature rise due to abnormality of the heat radiation module **20**. While the temperature sensor **31** detects the ambient temperature of the heating device **21**, the temperature sensor **71** detects the ambient temperature of the heat radiation module **20**. Specifically, the temperature sensor **71** functions as a first temperature sensor which detects the temperature at a first position on the printed circuit board **111**, which is close to the heat radiation module **20** (i.e. the board temperature near the heat radiation module **20**). The temperature sensor **71** is provided at the first position on the printed circuit board **111**, which is close to the heat radiation module **20**. When abnormality of the heat radiation module **20**, such as clogging of the heat radiation fin **23**, has occurred, heated air near the heat radiation fin **23** moves to the periphery of the heat radiation module **20**, for example, the periphery of the fan **22**. As a result, the board temperature near the heat radiation module **20** rises. The rise of the board temperature is detected by the temperature sensor **71**. In short, the temperature sensor **71**, like the temperature sensor **31**, functions as a sensor for detecting the temperature rise due to abnormality of the heat radiation module **20**.

[0134] The temperature sensor **71** may be disposed, for example, at either of a position indicated by a solid line in FIG. **14** or a position indicated by a broken line in FIG. **14**. However, the first position, where the temperature sensor **71** is disposed, should preferably be a position (the position indicated by the solid line in FIG. **14**) which is close to the heat radiation module **20** and is as distant as possible from the heating device **12**.

[0135] The temperature sensor **72**, like the above-described temperature sensor **32**, functions as a second temperature sensor which detects a reference temperature. The temperature sensor **72** detects the temperature at a second position (i.e. the intra-housing temperature) on the printed circuit board **111**, which is farther from each of the heating device **21** and heat radiation module **20** than the first position where the temperature sensor **71** is disposed. Specifically, the temperature sensor **72** is disposed at an end portion on the board **111** (i.e. a position indicated by a solid line or a broken line in FIG. **14**) which is hardly affected by the heat that is produced by the heating device **21** and which is far from the heat radiation module **20**. Specifically, the temperature sensor **72** is provided at an end position on the board **111** on the opposite side to the heat radiation module **20**, with the heating device **21** being interposed between the temperature sensor **72** and the heat radiation module **20**.

[0136] The temperature sensor **73** is provided at a third position on the board **111**, which is located between the inlet port **19** provided in the housing **11** and the heat radiation module **20**. The temperature sensor **73**, like the above-described temperature sensor **33**, is used as a third temperature sensor which detects the temperature at the third position on the board **111**, that is, the temperature of the air (cooling air) flowing from the inlet port **19** toward the heat radiation module **20**.

[0137] FIG. **15** shows the relationship between the power consumption of the computer **10**, and the board temperature in the vicinity of the heat radiation module and the intra-housing temperature.

[0138] In FIG. **15**, a solid line L**11** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **71** in the case where the heat radiation module **20** normally operates. A broken line L**12** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **71** in the case where the performance of the heat radiation module **20** has lowered. In the case where the performance of the heat radiation module **20** has lowered (for example, in the case where the performance of the fan has lowered, or clogging has occurred in the heat radiation fin), the inclination of the rise of the temperature detected by the temperature sensor **71** increases, as indicated by the broken line L**12**. A solid line L**13** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **72**. The detection temperature (intra-housing temperature) of the temperature sensor **72** is hardly influenced by the increase in power consumption of the heating device **21** or the lowering in performance of the heat radiation module **20**.

[0139] FIG. **16** shows the relationship between the power consumption of the computer **10**, and the temperature of cooling air and the intra-housing temperature.

[0140] In FIG. **16**, a solid line L**14** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **73** in the case where the heat radiation module **20** normally operates. A broken line L**15** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **73** in the case where the performance of the heat radiation module **20** has lowered. In the case where the performance of the heat radiation module **20** has lowered (for example, in the case where clogging has occurred in the heat radiation fin), the exhaust of air from the air outlet port **18** to the outside becomes unsmooth, and accordingly the suction of air from the air inlet port **19** becomes unsmooth. As a result, the temperature in the vicinity of the air inlet port **19** rises. Hence, the temperature detected by the temperature sensor **73** increases, as indicated by the broken line L**15**.

[0141] FIG. **17** shows the structure of a heat radiation performance measurement module **810** which is provided in the computer **10** according to the second embodiment.

[0142] The heat radiation performance measurement module **810** measures the performance of the heat radiation module **20** by using all the temperature sensors **71** to **73**, or by using only the temperature sensors **71** and **72** or only the temperature sensors **72** and **73**.

[0143] The heat radiation performance measurement module **810** includes a temperature difference detection module **811**, a temperature data acquisition module **812**, a perfor-

mance determination module **813**, a temperature data storing process module **814** and a fault symptom detection module **815**.

[0144] The temperature difference detection module **811** detects a temperature difference (T**1**−Tref) which is obtained by subtracting the temperature (Tref), which is detected by the temperature sensor **72**, from the temperature (T**1**) which is detected by the temperature sensor **71**. In addition, the temperature difference detection module **811** detects a temperature difference (T**2**−Tref) which is obtained by subtracting the temperature (Tref), which is detected by the temperature sensor **72**, from the temperature (T**2**) which is detected by the temperature sensor **73**.

[0145] The performance determination module **813** is activated when the temperature difference (T**1**−Tref), which is detected by the temperature difference detection module **811**, exceeds a certain specific threshold value TH**11**, or when the temperature difference (T**2**−Tref), which is detected by the temperature difference detection module **811**, exceeds a certain specific threshold value TH**12**. The performance determination module **813** continuously executes, during a predetermined time period from the time point when the temperature difference (T**1**−Tref) exceeds the threshold value TH**1**, a monitoring process of monitoring the temperature difference (T**1**−Tref) between the temperature (T**1**) that is detected by the temperature sensor **71** and the temperature (Tref) that is detected by the temperature sensor **72**. On the basis of the result of this monitoring process, the performance determination module **813** determines whether the performance of the heat radiation module **20** has lowered or not. In addition, the performance determination module **813** continuously executes, during a predetermined time period from the time point when the temperature difference (T**2**−Tref) exceeds the threshold value TH**12**, a monitoring process of monitoring the temperature difference (T**2**−Tref) between the temperature (T**2**) that is detected by the temperature sensor **73** and the temperature (Tref) that is detected by the temperature sensor **72**. On the basis of the result of this monitoring process, the performance determination module **813** determines whether the performance of the heat radiation module **20** has lowered or not.

[0146] In the meantime, at each of the time when the temperature difference (T**1**−Tref) that is detected by the temperature difference detection module **811** exceeds the threshold value TH**1** and the time when the temperature difference (T**2**−Tref) that is detected by the temperature difference detection module **811** exceeds the threshold value TH**12**, the performance determination module **813** may monitor the temperatures T**1**, T**2** and Tref for a predetermine time period, and may determine whether the performance of the heat radiation module **20** has lowered or not, by taking into account both the variation in the temperature difference (T**1**−Tref) during this time period and the variation in the temperature difference (T**2**−Tref) during this time period.

[0147] The monitoring process, which is executed by the performance determination module **813**, can be executed by the same procedure as has been described with reference to the flow chart of FIG. **10**.

[0148] The temperature data storing process module **814** stores temperature sample values corresponding to the temperatures T**1**, T**2** and Tref, which are acquired by the performance determination module **813** via the temperature data acquisition module **812** each time the monitoring process is executed, in the database **500** as temperature data. The fault symptom detection module **815** analyzes the temperature data that are accumulated in the database **500**, and detects a symptom relating to a fault of the heat radiation module **20**.

Third Embodiment

[0149] Next, still another example of arrangement of a plurality of temperature sensors, which are applied to the computer **10**, will be described as a third embodiment of the present invention. In the description below, only parts different from the first embodiment are mainly described.

[0150] FIG. **18** shows the positional relationship between a cooling mechanism which is provided in the housing **11**, and a plurality of temperature sensors. As shown in FIG. **18**, a heat radiation module **20**, a heating device **21**, and temperature sensors **81**, **82** and **83** are provided in the housing **11**.

[0151] An air outlet port **18** is provided in one side wall of the housing **11**. In addition, an air inlet port **19** is provided, for example, in another side wall of the housing **11**.

[0152] The temperature sensors **81** to **83** are provided on the printed circuit board **111**. Each of the temperature sensors **81** to **83** is composed of, for instance, a thermistor or a dedicated temperature sensor IC, which is attached on the printed circuit board **111**.

[0153] The temperature sensor **81**, like the above-described temperature sensor **31**, functions as a sensor for detecting a temperature rise due to abnormality of the heat radiation module **20**. The temperature sensor **81** detects the ambient temperature of the heating device **21**. Specifically, the temperature sensor **81** detects the temperature at a first position on the printed circuit board **111**, which is close to the heating device **21** and is located between the heating device **21** and the radiation module **20**. As shown in FIG. **18**, in the case where the left side of the heating device **21** is disposed to be opposed to the heat radiation module **20**, the temperature sensor **81** is disposed between the left side of the heating device **21** and the radiation module **20**, and detects the board temperature in the vicinity of the left side of the heating device **21**.

[0154] The temperature sensor **82**, like the above-described temperature sensor **32**, functions as a second temperature sensor which detects a reference temperature. The temperature sensor **82** detects the temperature at a second position (i.e. the intra-housing temperature) on the printed circuit board **111**, which is farther from each of the heating device **21** and heat radiation module **20** than the first position where the temperature sensor **81** is disposed. Specifically, the temperature sensor **82** is disposed at an end portion on the board **111** (i.e. a position indicated by a solid line or a broken line in FIG. **18**) which is hardly affected by the heat that is produced by the heating device **21** and which is far from the heat radiation module **20**. In other words, the temperature sensor **82** is provided at an end position on the board **111** on the opposite side to the heat radiation module **20**, with the heating device **21** being interposed between the temperature sensor **82** and the heat radiation module **20**.

[0155] The temperature sensor **83** is used in order to detect the ambient temperature of the heating device **21**. Specifically, the temperature sensor **83** detects the temperature at a third position on the printed circuit board **111** which is close to a side of the heating device **21**, which is other than the side thereof that is opposed to the heat radiation module **20**. In the case where the temperature sensor **81** is disposed near the left side of the heating device **21**, the temperature sensor **83** is disposed, for example, near the right side or lower side of the heating device **21**.

[0156] FIG. **19** shows the relationship between the power consumption of the computer **10**, and the detection temperatures of the temperature sensors **81**, **82** and **83**.

[0157] In a graph shown in the upper part of FIG. **19**, a solid line L**21** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **81** in the case where the heat radiation module **20** normally operates. A broken line t**22** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **81** in the case where the performance of the heat radiation module **20** has lowered. In the case where the performance of the heat radiation module **20** has lowered (for example, in the case where the performance of the fan has lowered, or clogging has occurred in the heat radiation fin), the inclination of the rise of the temperature detected by the temperature sensor **81** increases, as indicated by the broken line L**22**. A solid line L**23** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **82**. The detection temperature (intra-housing temperature) of the temperature sensor **82** is hardly influenced by the increase in power consumption of the heating device **21** or the lowering in performance of the heat radiation module **20**.

[0158] In a graph shown in the lower part of FIG. **19**, a solid line L**24** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **83** in the case where the heat radiation module **20** normally operates. A broken line L**25** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **83** in the case where the performance of the heat radiation module **20** has lowered. In the case where the performance of the heat radiation module **20** has lowered (for example, in the case where the performance of the fan has lowered, or clogging has occurred in the heat radiation fin), the inclination of the rise of the temperature detected by the temperature sensor **83** increases, as indicated by the broken line L**25**.

[0159] As is understood from FIG. **19**, if a fault, such as clogging of the heat radiation fin **23**, has occurred, the heat of the heating device **21** is not easily exhausted to the outside, and both the temperature detected by the temperature sensor **81** and the temperature detected by the temperature sensor **83** increase, compared to the case in which the heat radiation module **20** normally operates.

[0160] FIG. **20** shows another example of the relationship between the power consumption of the computer **10**, and the detection temperatures of the temperature sensors **81**, **82** and **83**.

[0161] In a graph shown in the upper part of FIG. **20**, a solid line L**21** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **81** in the case where the heat radiation module **20** normally operates. A broken line L**22** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **81** in the case where there has occurred a factor other than the clogging of the heat radiation fin **23** (e.g. heat production due to a fault of a device **300** in FIG. **18**). If there has occurred a factor other than the clogging of the heat radiation fin **23** (e.g. heat production due to a fault of the device **300** in FIG. **18**), the detection temperature of the temperature sensor **81** rises, as indicated by the broken line t**22**.

[0162] In a graph shown in the lower part of FIG. **20**, a solid line L**24** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **83** in the case where the heat radiation module **20** normally operates. A broken line L**25** indicates the relationship between the power consumption and the detection temperature of the temperature sensor **83** in the case where there has occurred a factor other than the clogging of the heat radiation fin **23** (e.g. heat production due to a fault of the device **300** in FIG. **18**). Even if there has occurred a factor other than the clogging of the heat radiation fin **23** (e.g. heat production due to a fault of the device **300** in FIG. **18**), the detection temperature of the temperature sensor **83** hardly varies, as indicated by the broken line L**25**.

[0163] As is understood from FIG. **19** and FIG. **20**, when a fault occurs in the heat radiation fin **23**, both the detection temperatures of the temperature sensors **81** and **83** increase. On other hand, in the case of a factor other than the fault of the heat radiation fin **23**, only the detection temperature of the temperature sensor **81** rises, and the detection temperature of the temperature sensor **83** hardly varies. Therefore, by monitoring the detection temperatures of the temperature sensors **81**, **82** and **83**, it becomes possible to determine not only the lowering of the heat radiation performance, but also the factor of the lowering of the heat radiation performance.

[0164] FIG. **21** shows the structure of a heat radiation performance measurement module **910** which is provided in the computer **10** according to the third embodiment.

[0165] The heat radiation performance measurement module **910** measures the performance of the heat radiation module **20** by using all the temperature sensors **81** to **83**.

[0166] The heat radiation performance measurement module **910** includes a temperature difference detection module **911**, a temperature data acquisition module **912**, a performance determination module **913**, a temperature data storing process module **914** and a fault symptom detection module **915**.

[0167] The temperature difference detection module **911** detects a temperature difference (T**1**−Tref) which is obtained by subtracting the temperature (Tref), which is detected by the temperature sensor **82**, from the temperature (T**1**) which is detected by the temperature sensor **81**. In addition, the temperature difference detection module **911** detects a temperature difference (T**2**−Tref) which is obtained by subtracting the temperature (Tref), which is detected by the temperature sensor **82**, from the temperature (T**2**) which is detected by the temperature sensor **83**.

[0168] The performance determination module **913** is activated when the temperature difference (T**1**−Tref), which is detected by the temperature difference detection module **911**, exceeds a certain specific threshold value TH**11**, or when the temperature difference (T**2**−Tref), which is detected by the temperature difference detection module **911**, exceeds a certain specific threshold value TH**12**. The performance determination module **913** continuously executes, during a predetermined time period from the time point when the temperature difference (T**1**−Tref) or the temperature difference (T**2**−Tref) exceeds the corresponding threshold value, a monitoring process of monitoring the temperature (TI) that is detected by the temperature sensor **81**, the temperature (Tref) that is detected by the temperature sensor **82**, and the temperature (T**2**) that is detected by the temperature sensor **83**. On the basis of the result of this monitoring process, the performance determination module **913** determines whether the performance of the heat radiation module **20** has lowered or not. In this monitoring process, the presence/absence of the

clogging of the heat radiation fin **23** can also be determined. In the monitoring process, the performance determination module **913** acquires the detection temperatures of the temperature sensors **81**, **82** and **83** via the temperature data acquisition module **912**.

[0169] The monitoring process, which is executed by the performance determination module **913**, can also be executed by the same procedure as has been described with reference to the flow chart of FIG. **10**.

[0170] The temperature data storing process module **914** stores temperature sample values corresponding to the temperatures T**1**, T**2** and Tref, which are acquired by the performance determination module **913** via the temperature data acquisition module **912** each time the monitoring process is executed, in the database **500** as temperature data. The fault symptom detection module **915** analyzes the temperature data that are accumulated in the database **500**, and detects a symptom relating to a fault of the heat radiation module **20**.

[0171] The various modules of the systems described herein can be implemented as software applications, hardware and/or software modules, or components on one or more computers, such as servers. While the various modules are illustrated separately, they may share some or all of the same underlying logic or code.

[0172] While certain embodiments of the inventions have been described, these embodiments have been presented by way of example only, and are not intended to limit the scope of the inventions. Indeed, the novel methods and systems described herein may be embodied in a variety of other forms; furthermore, various omissions, substitutions and changes in the form of the methods and systems described herein may be made without departing from the spirit of the inventions. The accompanying claims and their equivalents are intended to cover such forms or modifications as would fall within the scope and spirit of the inventions.

What is claimed is:

1. An information processing apparatus comprising:

a housing;

a printed circuit board provided in the housing;

a heating device disposed on the printed circuit board;

a heat radiation module provided in the housing, configured to exhaust heat of the heating device to outside;

a first temperature sensor configured to detect a temperature at a first position on the printed circuit board;

a second temperature sensor configured to detect a temperature at a second position on the printed circuit board, which is farther from the heating device than the first position;

a temperature difference detection module configured to detect a temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the first position detected by the first temperature sensor; and

a performance determination module configured to be activated when the detected temperature difference exceeds a threshold value, to execute a monitoring process of monitoring the temperature difference between the temperature at the first position and the temperature at the second position during a predetermined period from a time point when the detected temperature difference exceeds the threshold value, and to determine, based on a result of the monitoring process, whether a performance of the heat radiation module has lowered or not.

2. The information processing apparatus of claim **1**, wherein the performance determination module is configured to repeatedly execute, during the predetermined period at predetermined time intervals, a process of acquiring pairs of a first temperature sample value indicative of the temperature at the first position detected by the first temperature sensor and a second temperature sample value indicative of the temperature at the second position detected by the second temperature sensor, and to determine whether the performance of the heat radiation module has lowered or not, based on the pairs acquired during the predetermined period.

3. The information processing apparatus of claim **2**, wherein the performance determination module is configured to calculate a number of pairs which are included in the pairs acquired during the predetermined period and in which a difference that is obtained by subtracting the second temperature sample value from the first temperature sample value exceeds a reference value, and to determine, based on the calculated number, whether the performance of the heat radiation module has lowered or not.

4. The information processing apparatus of claim **1**, wherein the performance determination module is configured to determine, at predetermined time intervals, whether the temperature difference exceeds the threshold value or not, to execute, on condition that the temperature difference exceeds the threshold, a process of acquiring pairs of a first temperature sample value indicative of the temperature at the first position detected by the first temperature sensor and a second temperature sample value indicative of the temperature at the second position detected by the second temperature sensor, and to determine whether the performance of the heat radiation module has lowered or not, according to whether a predetermined number of pairs have been acquired during the predetermined period.

5. The Information processing apparatus of claim **1**, wherein the performance determination module is configured to determine, at predetermined time intervals, whether the temperature difference exceeds the threshold value or not, to execute, on condition that the temperature difference exceeds the threshold, a process of acquiring pairs of a first temperature sample value indicative of the temperature at the first position detected by the first temperature sensor and a second temperature sample value indicative of the temperature at the second position detected by the second temperature sensor, to calculate, in a case where a predetermined number of pairs have been acquired during the predetermined period, a number of pairs which are included in the predetermined number of pairs and in which a difference that is obtained by subtracting the second temperature sample value from the first temperature sample value exceeds a reference value, and to determine that the performance of the heat radiation module has lowered, in a case where the calculated number of pairs exceeds a reference number.

6. The information processing apparatus of claim **2**, further comprising:

a temperature data storing process module configured to store pairs of the first temperature sample value and the second temperature sample value, which are acquired by the performance determination module each time the monitoring process is executed, in a storage device as one set of temperature data; and

a fault symptom detection module configured to analyze, after a plurality of sets of temperature data have been stored in the storage device, the plurality of sets of tem-

perature data, and to detect a symptom relating to a fault of the heat radiation module, from a tendency of temperature variation at the first position, which is indicated by the plurality of sets of temperature data.

7. The information processing apparatus of claim **1**, further comprising a third temperature sensor configured to detect a temperature at a third position on the printed circuit board, which is located between an air inlet port provided in the housing and the heat radiation module,

wherein the performance determination module is configured to detect clogging of the air inlet port in accordance with a temperature difference between the temperature detected by the third temperature sensor and the temperature at the second position detected by the second temperature sensor.

8. The information processing apparatus of claim **1**, wherein the heat radiation module includes:

a heat radiation fin provided at a position in the housing, which is opposed to an air outlet port provided in the housing, and thermally connected to the heating device; and

a fan configured to cool the heat radiation fin.

9. The information processing apparatus of claim **8**, further comprising:

a power supply current detection module configured to detect a power supply current which is supplied to the fan; and

a heat radiation fin abnormality detection module configured to detect clogging of the heat radiation fin, based on a relationship between a rotation number of the fan and the detected power supply current.

10. The information processing apparatus of claim **1**, wherein the heating device is a central processing unit.

11. An information processing apparatus comprising:

a housing;

a printed circuit board provided in the housing;

a heating device disposed on the printed circuit board;

a heat radiation module provided in the housing, configured to exhaust heat of the heating device to outside;

a first temperature sensor configured to detect a temperature at a first position on the printed circuit board;

a second temperature sensor configured to detect a temperature at a second position on the printed circuit board, which is farther from each of the heat radiation module and the heating device than the first position;

a temperature difference detection module configured to detect a temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the first position detected by the first temperature sensor; and

a performance determination module configured to be activated when the detected temperature difference exceeds a threshold value, to execute a monitoring process of monitoring the temperature difference between the temperature at the first position and the temperature at the second position during a predetermined period from a time point when the detected temperature difference exceeds the threshold value, and to determine, based on a result of the monitoring process, whether a performance of the heat radiation module has lowered or not.

12. The information processing apparatus of claim **11**, further comprising a third temperature sensor configured to detect a temperature at a third position on the printed circuit board, which is located between an air inlet port provided in the housing and the heat radiation module,

the performance determination module is configured to execute, in a case where another temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the third position detected by the third temperature sensor exceeds a threshold, another monitoring process of monitoring the temperature difference between the temperature at the third position and the temperature at the second position during a predetermined period from a time point when said another temperature difference exceeds a threshold value, and to determine, based on a result of said another monitoring process, whether the performance of the heat radiation module has lowered or not.

13. An information processing apparatus comprising:

a housing;

a printed circuit board which is configured to be provided in the housing;

a heating device disposed on the printed circuit board;

a heat radiation module provided in the housing, configured to exhaust heat of the heating device to outside;

a first temperature sensor configured to detect a temperature at a first position on the printed circuit board, which is located between the heating device and the heat radiation module;

a second temperature sensor configured to detect a temperature at a second position on the printed circuit board, which is farther from the heating device than the first position;

a third temperature sensor configured to detect a temperature at a third position on the printed circuit board, which is closed to a side of the heating device, said side being other than a side thereof that is opposed to the heat radiation module;

a temperature difference detection module configured to detect a first temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the first position detected by the first temperature sensor, and a second temperature difference which is obtained by subtracting the temperature at the second position detected by the second temperature sensor from the temperature at the third position detected by the third temperature sensor; and

a performance determination module configured to be activated when one of the detected first temperature difference and the detected second temperature difference exceeds a threshold value, to execute a monitoring process of monitoring the temperature at the first position, the temperature at the second position and the temperature at the third position during a predetermined period from a time point when the one of the detected first temperature difference and the detected second temperature difference exceeds the threshold value, and to determine, based on a result of the monitoring process, whether a performance of the heat radiation module has lowered or not.

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