

# **Environment Management System for Electronic Devices**

## **Technical Field**

The present invention generally relates to an  
5 environment management system for electronic devices. The  
present invention also relates to a method of managing  
the environment of an electronic device.

## **Background**

10 Electronic devices, such as microprocessors, are  
designed to operate within certain temperature ranges.  
In operation these devices generate heat. If the heat  
generated by the electronic devices is dissipated  
inadequately, the electronic devices may operate outside  
15 of their designed temperature ranges. Frequent operation  
of the electronic devices above their designed  
temperature range may cause the electronic devices to  
fail prematurely. Furthermore, if the temperature of the  
devices exceeds a particular threshold, the electronic  
20 devices may suffer permanent damage.

In a military aircraft, electronic devices, such as  
avionics equipment and electronic card cages, may be  
mounted in electronic racks. Forced air cooling is  
25 normally employed to dissipate heat that is generated by  
these electronic devices. The electronic racks are  
linked to a cold air distribution network which channels  
a pre-determined flow rate of cold air into each of the  
electronic racks to cool the electronic devices stored  
30 therein.

A known environment management system comprises an  
enclosure for housing electronic devices, which generate  
heat inside the enclosure. A fan is used to blow air

over the electronic devices to ensure that the devices are kept cool in operation. The fan has a speed that is responsive to an input signal. The enclosure has a temperature sensor mounted to an inlet of the enclosure that allows air to pass therethrough. The temperature sensor measures the temperature entering the enclosure. A controller adjusts the speed of the fan until the temperature inside the enclosure is within a predetermined range to ensure that the electronic devices inside the enclosure do not overheat.

A disadvantage with known environment management systems for electronic devices is that the system does not detect overheating of devices located within the enclosure, because the temperature sensor is disposed at the air inlet and cannot measure downstream temperature flow.

A further disadvantage with known environment management systems is that the systems only detect temperature, thereby limiting the number of indicators that can be used to determine if devices within the enclosure are overheating. Furthermore, the provision of only one detector means that the environment management system ceases to function if the temperature sensor fails.

There is a need to provide an environment management system for electronic devices that overcomes or at least ameliorates one or more of the disadvantages described above.

### Summary

According to a first aspect of the invention, there is provided an environment management system for an electronic device, the environment management system  
5 comprising:

a casing having an air intake opening and an air exhaust opening, the casing capable of housing the electronic device, the electronic device capable of producing heat;

10 an air moving unit for moving air from the air intake opening, past the electronic device and to the air exhaust opening;

an exhaust sensor for detecting one or more parameters of the air after the air passes the electronic  
15 device; and

a controller electrically coupled to the exhaust sensor for receiving one or more signals representative of the detected one or more parameters of the air, the controller being responsive to the one or more signals to  
20 generate an alert in the event that one or more of the signals deviate from a predefined parameter range.

In one embodiment of the first aspect, the environment management system may comprise an intake  
25 sensor electrically coupled to the controller, the intake sensor capable of detecting the one or more parameters of the air before the air passes the electronic device.

According to a second aspect of the invention, there  
30 is provided a method of managing the environment of an electronic device disposed within a casing having an air intake opening and an air exhaust opening, the method comprising:

moving air past the electronic device;

detecting one or more parameters of the air after the air passes the electronic device;

monitoring the detected one or more parameters of the air; and

5       generating an alert when one or more of the detected parameters of the air deviates from a predefined parameter range.

10       In one embodiment of the second aspect, the method may comprise the step of detecting one or more parameters of the air before the air passes the electronic device.

15       According to a third aspect of the invention, there is provided an environment management system for an electronic device, the environment management system comprising:

20       a casing having an air intake opening and an air exhaust opening, the casing capable of housing a plurality of electronic devices, , the electronic devices capable of generating heat;

      a primary air moving unit for moving air at a first flow rate through the air intake opening, into the casing and out through the air exhaust opening;

25       an air cooling module comprising a primary duct, a plurality of spray bars in fluid communication with the primary duct and a secondary air moving unit for moving air, at a second flow rate, from the primary duct through to the plurality of spray bars, the air cooling module being mounted within the casing such that, in use, the  
30       spray bars direct air onto the electronic devices;

      at least one exhaust sensor for detecting one or more parameters of the air after the air has been sprayed onto the electronic devices; and

a controller electrically coupled to the exhaust sensor for receiving one or more signals representative of the detected one or more parameters of the air, the controller being responsive to the one or more signals to  
5 generate an alert in the event that one or more of the signals deviate from a predefined range.

In one embodiment of the third aspect, the system may comprise one or more intake sensors for detecting the  
10 one or more parameters of the air before the air passes the one or more electronic devices.

According to a fourth aspect of the invention, there is provided an environment management system for an  
15 electronic device, the environment management system comprising:

a casing having an air intake opening and an air exhaust opening, the casing capable of housing the electronic device, the electronic device capable of  
20 producing heat;

an air moving unit for moving air from the air intake opening, past the electronic device and to the air exhaust opening;

one or more sensors for detecting two or more  
25 parameters of air within the casing; and

a controller electrically coupled to the one or more sensors for receiving signals representative of the detected two or more parameters of the air, the controller being responsive to the signals to generate an  
30 alert in the event that one of the two or more signals deviates from a predefined parameter range.

### **Disclosure of embodiments**

In one embodiment, the controller may be electrically coupled to the electronic device and may be responsive to the signals to render the electronic device  
5 inoperative in the event that one or more of the signals deviate from a second predefined range.

The casing may have a plurality of air intake openings. The casing may comprise an air intake  
10 perforated plate having the plurality of air intake openings extending through the perforated plate. An air supply duct may be provided on one side of the air intake perforated plate for supplying air from the air moving unit in use.

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The casing may have a plurality of air exhaust openings. The casing may comprise an air exhaust perforated plate having the plurality of air exhaust openings extending through the air exhaust perforated  
20 plate. An air exhaust duct may be provided on one side of the air exhaust perforated plate for allowing air moved by the air moving unit to be expelled therefrom in use.

In one embodiment the electronic device is a  
25 microprocessor for processing data. The controller may be configured to save any data associated with the microprocessor in a data storage medium, prior to rendering the microprocessor inoperative. A plurality of electronic devices may be mounted within the casing.

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In one embodiment, a plurality of air moving units may be provided to move air. The air moving unit may be provided inside or outside of the casing. In one embodiment, the air moving unit may be provided outside

the casing to push air into the air intake opening or to suck air into the air intake opening. In another embodiment, the air moving unit may be provided inside the casing to suck air into the air intake opening and to  
5 push air out of the air exhaust opening.

The air moving unit may be a fan or a blower.

The air may be conditioned air in that the air may  
10 be at a cold temperature for cooling the electronic device provided within the casing. The conditioned air may be at a temperature in the range of about 5°C to about 18°C. The conditioned air may be at a relative humidity in the range of 20% to 60% preferably 30% to  
15 50%.. The conditioned air may be supplied from an air cooling source.

The air may follow an air movement path that extends from the air intake opening, past the electronic device  
20 and through to the air exhaust opening.

The fan may be a variable speed type equipped with a controller. The speed of fan may be determined by the controller, which the controller may be programmed to  
25 alter the speed of fan depending on the temperature detected within the casing. For instance, the speed of the fan can be increased by the controller if the controller senses a temperature which reaches a certain limit.

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The intake sensor may be provided along the air movement path between the air intake opening and the electronic device. The intake sensor may be provided adjacent the air intake opening along the air movement

path. Alternatively, the intake sensor may be provided outside of the casing and adjacent to the air intake opening. In one embodiment, the system comprises a plurality of air intake sensors.

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The exhaust sensor may be provided along the air movement path between the electronic device and the air exhaust opening. The exhaust sensor may be provided adjacent the exhaust opening along the air movement path.

10 Alternatively, the exhaust sensor may be provided outside of the casing and adjacent to the air exhaust opening. In one embodiment, the system comprises a plurality of air exhaust sensors. Each of the plurality of exhaust sensors may be associated with a plurality of electronic devices.

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The one or more parameters of the air may be selected from the group consisting of: air temperature; air pressure; air speed; relative humidity; smoke presence; and air flow rate.

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The alert generated by the controller may be used to indicate the environmental conditions within the casing. The alert generated by the controller may indicate one or more environmental conditions such that: the air is within a high temperature range; that the air is within a low temperature range; that the temperature within the casing will cause the electronic device to cease functioning; or that the air moving unit has ceased to function.

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In one embodiment, the system may comprise a user interface on which the alert is generated. The user interface may be a graphical user interface. In one embodiment, the graphical user interface may be a display

monitor. In another embodiment, the user interface may be an indicator panel comprising one or more indicator lights thereon, the one or more indicator lights capable illumination upon generation of the alert. The one or  
5 more indicator lights may also comprise text indicating a condition of the alert. In another embodiment, the system may comprise an audio generator for generating the alert as an audio signal.

10 In an embodiment that comprises an air cooling module mounted within the casing, the air cooling module may comprise a plurality of secondary ducts connecting the primary duct to the plurality of spray bars. The plurality of secondary ducts may be mounted orthogonally  
15 to the primary duct. The secondary air moving unit may be mounted within the primary duct.

#### **Brief Description Of Drawings**

The accompanying drawings which are incorporated  
20 into and constitute apart of the description of the invention, illustrate two disclosed embodiments and serve to explain the principles of the disclosed embodiments. It is to be understood, however, that the drawings are disclosed for purposes of illustration only, and not as a  
25 definition of the limits of the invention.

Fig. 1 shows a cross-sectional front view of an environment management system for a plurality of electronic devices;

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Fig. 1a shows a block diagram of a control system of the environment management system of Fig. 1;

Fig. 2 shows a flow chart of an overview of an algorithm that is used by the control system of Fig. 1a;

Fig. 2a is a flow diagram showing more detail of one  
5 of the steps of the algorithm of Fig. 2;

Fig. 2b is another flow diagram showing more detail of another of the steps of the algorithm of Fig. 2;

10 Fig. 2c is a further flow diagram showing yet further steps of the algorithm of Fig. 2;

Fig. 3a is a simplified perspective view of a second embodiment of an environment management system;  
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Fig. 3b shows a perspective view of the casing of Fig. 3a in a simplified configuration with electronic card cages (shown in bold lines) mounted therein;

20 Fig. 4a shows a perspective view of the casing of Fig. 3a in a simplified configuration showing a possible mounting mechanism for mounting the electronic card cages; and

25 Fig. 4b shows a perspective view of an electronic card cage.

### **Detailed Description**

Two exemplary non-limiting embodiments of an  
30 environment management system for electronic devices are now disclosed hereinafter. The environment management system comprises a casing that has an air intake opening and an air exhaust opening. The electronic devices are disposed within the casing and are capable of producing

heat when in use. An air moving unit moves air from the air intake opening, past the electronic devices and to the air exhaust opening. The environment management system also comprises an intake sensor for detecting at least one parameter of the air before the air passes the electronic devices and an exhaust sensor for detecting the parameter of the air after the air passes the electronic devices. A controller is also provided that is electrically coupled to the intake sensor and the exhaust sensor for receiving signals representative of the detected parameter of the air. In use the controller is responsive to the signals to generate an alert in the event that one or more of the signals deviates from a predefined range.

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Referring now to Fig. 1 there is shown a cross-sectional front view of an environment management system 10' that is used to manage the environment in which electronic devices reside. In this embodiment, the electronic devices are in the form of a plurality of microprocessors 12'. The plurality of microprocessors 12' are mounted on racks (not shown) within a casing in the form of cabinet 14'. In this embodiment, the cabinet 14' is provided on an aircraft and the microprocessors 12' process data to support different systems of the aircraft.

The cabinet 14' comprises a top wall 3', a bottom wall 4', two side walls (5',6'), a partition wall 7' extending vertically through the middle of the cabinet 14', and front wall and rear walls that are not marked on the drawing.

The cabinet 14' also includes air intake openings in the form of a plurality of inlet openings 16' which extend through a perforated plate 18' that is provided adjacent to the bottom wall 4'. The cabinet 14' also includes two air exhaust openings in the form of outlet 20' provided in the top wall 3' of the cabinet 14' and outlet 22' provided on the rear side wall and shown by dash lines 36'.

The system 10' also includes an air moving unit in the form of a fan 24'. In other embodiments, the fan might be a blower. Fan 24' is mounted within a distribution duct 26', which extends along and adjacent to the perforated plate 18'. The duct 26' is in fluid communication with a refrigeration source provided on the aircraft. The refrigeration source provides cooling air along the duct 26' and through to the inlet 16'. The fan 24' blows the cold air from the inlet 16' to the outlets (20', 22') so that the cold air passes over the microprocessors 12'.

The microprocessors 12' generate heat in use and accordingly the cold air passing over the microprocessors 12', causes the microprocessors to cool down. An exemplary air movement path is shown by dash lines 36' extending from duct 26' to one of the inlets 16', extending past the microprocessors 12' and out through the outlet 20'. Accordingly, heat generated by the microprocessors 12' is removed by the air as the air passes over, thereby maintaining the temperature of the microprocessors 12' in a desired operating range.

The system 10' also comprises air intake sensors in the form of fan sensor (F1); inlet temperature sensor

(T1) and static differential pressure sensor, with built-in transmitter (P1), which are mounted adjacent to one of the inlets 16' on the left side of the cabinet 14'. An additional fan sensor (F2) is also provided adjacent  
5 another inlet 16' on the right side of the cabinet 14'.

The system 10' also comprises exhaust sensors in the form of temperature sensor (T2) that is mounted adjacent to the outlet 20' and temperature sensor (T3) that is  
10 mounted adjacent to the outlet 22'.

The sensors (T1,T2,T3,F1,F2,P1) are commercially available.

The temperature sensors (T1,T2,T3) measure the  
15 temperature of the air passing through the cabinet 14'. The temperature sensors may be platinum-resistance high-accuracy sensors. Exemplary platinum-resistance high-accuracy sensors are commercially available from Acez Instruments Pte Ltd of Singapore. The temperature sensors  
20 (T1, T2, T3) are respectively powered by temperature transmitters (TT1, TT2, TT3) shown in Fig. 1A.

The fan sensors (F1, F2) measure the speed of air in flowing through the cabinet 14'. Exemplary fan sensors  
25 are available commercially from Ametek Rotron of Paoli, Pennsylvania of United States of America.

The pressure sensor (P1) is a static differential pressure sensor (with built-in transmitter) and measures  
30 the static difference between the pressure of the cabinet 14' and the pressure of the environment outside of the cabinet 14'. Exemplary static differential pressure sensors are available commercially from Flotech Controls Pte Ltd of Singapore.

A controller in the form of Central Control Unit (CCU) 28' is also mounted within the cabinet 14' adjacent to the outlet 22'. The controller is electrically connected to the sensors (T1, T2, T3, F1, F2, P1). In  
5 another embodiment, the CCU 28' may control the operation of the fan 24'. The CCU 28' has a memory (not shown) for storage of a set of commands for operating the environment management system, as is described hereinafter, and a processor (not shown) for processing  
10 data associated with the set of commands. An exemplary CCU that is available commercially includes a Synco™ 700 controller from Siemens AG, of Munich, Germany.

The CCU 28' is also connected to a user interface in  
15 the form of indicator panel 30' that is shown in schematic diagram Fig. 1a, which shows a block diagram of the control system 15' for CCU 28'. The sensors (F1,F2,P1) have transmitters built in and are shown as being coupled directly to the CCU 28'. Each of the  
20 temperature sensors (T1, T2, T3) are respectively directly coupled to the temperature transmitters (TT1,TT2,TT3) for powering the sensors and converting the detected transmitter signal into an amplified digital signal for the CCU 28'.

25

The operation of the environment management system 10' is now described hereinafter. The environment management system 10' is used to manage the environment of the microprocessors 12'. The system 10' involves  
30 forcing cooling air past the microprocessors 12' and using the sensors (T1,F1,F2,P1) to detect parameters of the cold air before passing the microprocessors 12' and sensors (T2,T3) after the air has passed the microprocessors 12'. The CCU 28' monitors the sensors

(T1,T2,T3,F1,F2,P1) and generates alerts in the event that one of the monitored parameters of the air deviates from a predefined range.

5       The system 10' does not operate in the initial startup phase of the microprocessors 12' as the aircraft air conditioning system is initially in a heating mode to provide warm dry air to the cabinet 14' for a predefined period of time via the duct 26'. The warm dry air ensures  
10   that the electronics within the cabinet 14' are adequately dehumidified before operation.

      After the drying period, the air conditioning system automatically switches over from the heating mode to a  
15   cooling mode to supply cold air to the duct 26'. The cold air is continuously supplied to the duct 26' while the microprocessors 12' are in operation.

      Referring now to Fig. 2, there is shown a block  
20   diagram of an algorithm representing the set of instructions that reside in the memory of the CCU 28' to monitor the environment of the microprocessors 12'.

      The CCU 28' is switched on at step S1.  
25

      In Step 2 the CCU 28' performs a built-in test to determine whether the measured parameters of the sensors (T1,T2,T3,F1,F2,P1) falls within the valid ranges. The valid ranges are programmed into the memory of the CCU  
30   28' as "operating parameter ranges". The operating parameter ranges are chosen so that the parameters fall within a "safe" operating range, that is a range that does not adversely affect the operation of the microprocessors 12'.

In step S2A, the CCU 28' is programmed to interrogate the sensors (T1,T2,T3,F1,F2,P1), which respectively transmit their detected signals of their  
5 measured parameters to the CCU 28'. The CCU 28' uses these measured parameters in steps S2B, S3, S8 and S19 to determine if the transmitted parameters are within the operating parameter ranges as is described hereinafter in further detail below. If one of the measured parameters  
10 of the sensors (T1,T2,T3,F1,F2,P1) falls outside of the operating parameter ranges, one or more alerts are generated by the CCU 28' in step S2C. The alerts indicate either that the rack is overheating (generated as an "Rack Overheat" alert) or that the rack is about to be  
15 shutdown (generated as a "Rack Shutdown" alert), in which case the microprocessors 12' are rendered inoperative. These alerts are displayed via an illumination lamp provided on the indication panel 30'.

20 In step S2B, the CCU 28' reads the following signals generated by sensors (T1,T2,T3,F1,F2,P1):

- T1 (the "T1 sensor value");
- T2 (the "T2 sensor value");
- T3 (the "T3 sensor value");
- 25 • F1 (the "F1 sensor value");
- F2 (the "F2 sensor value"); and
- P1 (the "P1 sensor value").

At steps (S3,S8,S19), the CCU 28' is programmed to  
30 compare the above values so that if any one of the conditions listed in Table 1 are met, the CCU 28' generates an alert at step S2C.

**Table 1**

| <b>Measured Value</b> | <b>Condition</b> | <b>Alert generated</b> |
|-----------------------|------------------|------------------------|
| T1 sensor value       | $T1 \geq T1W$    | Rack Overheat          |
| T1 sensor value       | $T1 \geq T1S$    | Rack Shutdown          |
| T2 sensor value       | $T2 \geq T2W$    | Rack Overheat          |
| T2 sensor value       | $T2 \geq T2S$    | Rack Shutdown          |
| T3 sensor value       | $T3 \geq T3W$    | Rack Overheat          |
| T3 sensor value       | $T3 \geq T3S$    | Rack Shutdown          |
| F1 sensor value       | $F1 \leq F1W$    | Rack Overheat          |
| F1 sensor value       | $F1 \leq F1S$    | Rack Shutdown          |
| F2 sensor value       | $F2 \leq F2W$    | Rack Overheat          |
| F2 sensor value       | $F2 \leq F2S$    | Rack Shutdown          |
| P1 sensor value       | $P1 \leq P1W$    | Rack Overheat          |
| P1 sensor value       | $P1 \leq P1S$    | Rack Shutdown          |

Where:

- T1W,T2W,T3W are respectively temperature warning set points for T1,T2,T3 sensor values;
- T1S,T2S,T3S are respectively temperature shutdown set points for T1,T2,T3 sensor values;
- F1W,F2W are respectively air flow rate warning set points for F1,F2 sensor values;
- F1S,F2S are respectively air flow rate shut down set points for F1,F2 sensor values;
- P1W is an air differential pressure warning set point for P1 the sensor value; and
- P1S is an air differential pressure shutdown set point for P1 the sensor value.

Referring now in particular to step S3, the CCU 28' checks the detected inlet sensor values (P1,T1). A detailed view of the algorithm for checking the inlet

sensor values (P1,T1) is shown in Fig. 2A. At step S4 of figure 2A, the CCU 28' is programmed to determine if  $P1 \leq P1W$ . If P1 sensor value  $\leq P1W$  set point, the system proceeds to step S3A in which the Rack Overheat light on the indicator panel 30' is illuminated (Step 3A). The CPU 28' then progresses to step S6. If P1 sensor value  $> P1W$ , processing continues at step S6.

If in step S4, P1 sensor value  $> P1W$  set point, the CPU 28' is programmed to progress to step S6 in which the T1 sensor value is checked to determine if T1 sensor value  $\geq T1W$  set point. If T1 sensor value  $\geq T1W$  set point, the CCU 28' illuminates the Rack Overheat Light on the indicated panel 30' (Step 3B). The CPU 28' is programmed to progress to S8, which is shown in detail in Fig. 2B. If  $T1 < T1W$ , processing continues from step S6 to step S8.

At step S8, the CCU 28' checks the detected inlet sensor values (F1,F2). At step S9, the CCU 28' is programmed to determine if F1 sensor value  $\leq F1S$  set point. If F1 sensor value  $\leq F1S$  set point, the system proceeds to step S3B in which the Rack Shutdown light on the indicator panel 30' is illuminated. The CPU 28' is programmed to initiate a shutdown of the operation of the microprocessors 12' (Step S11). Processing continues at step S19.

If in step S9, F1 sensor value  $> F1S$  set point, the CPU 28' is programmed to proceed to step S12 in which the F1 sensor value is measured to determine if F1 sensor value  $\leq F1W$  set point. If F1 sensor value  $\leq F1W$  set point, the system proceeds to step S3A in which the Rack Overheat light on the indicator panel 30' is illuminated.

If F1 sensor value  $\geq$  F1W set point, the system proceeds to step S14.

At step S14, the CCU 28' is programmed to determine  
5 if F2 sensor value  $\leq$  F2S set point. If F2 sensor value  $\leq$   
F2S set point, the system proceeds to step S3B in which  
the Rack Shutdown light on the indicator panel 30' is  
illuminated. The CPU 28' is then programmed to initiate  
a shutdown of the operation of the microprocessors 12'  
10 (Step S16).

If in step S14, F2 sensor value  $\geq$  F2S set point, the  
CPU 28' is programmed to proceed to step S17 in which the  
F2 value is processed to determine if F2 sensor value  $\leq$   
15 F2W set point. If F2 sensor value  $\leq$  F2W set point, the  
CPU 28' proceeds to step S3A in which the Rack Overheat  
light on the indicator panel 30' is illuminated. If F2  
sensor value  $\geq$  F2W set point, the system proceeds to step  
S19, which is shown in detail in Fig. 2C.

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Referring to Fig. 2C, at step S19 the CCU 28' checks  
the detected exit sensor values (T2, T3). At step S20,  
the CCU 28' is programmed to determine if T2 sensor value  
 $\geq$  T2S set point. If T2 sensor value  $\geq$  T2S set point, the  
25 system proceeds to step S3B in which the Rack Shutdown  
light on the indicator panel 30' is illuminated. The  
CPU 28' is then programmed to initiate a shutdown of the  
operation of the microprocessors 12' (Step S22).

30 If in step S20, T2 sensor value  $\geq$  T2S set point, the  
CPU 28' is programmed to proceed to step S23 in which the  
T2 sensor value is measured to determine if T2 sensor  
value  $\geq$  T2W set point. If T2 sensor value  $\geq$  T2W set point,  
the system proceeds to step S3A in which the Rack

Overheat light on the indicator panel 30' is illuminated.  
If T2 sensor value < T2W set point, the system proceeds to  
step S25.

5       At step S25, the CCU 28' is programmed to determine  
if T3 sensor value  $\geq$  T3S set point. If T3 sensor value  $\geq$   
T3S set point, the CCU 28' is programmed to proceed to  
step S3B in which the Rack Shutdown light on the  
indicator panel 30' is illuminated. The CPU 28' is then  
10   programmed to initiate a shutdown of the operation of the  
microprocessors 12' (Step S27).

      If in step S25, T3 sensor value < T3S set point, the  
CPU 28' is programmed to proceed to step S28 in which the  
15   T3 sensor value is processed to determine if T3 sensor  
value  $\geq$  T3W set point. If T3 sensor value  $\geq$  T3W set point,  
the system proceeds to step S3A in which the Rack  
Overheat light on the indicator panel 30' is illuminated.  
If T3 sensor value < T3W set point, the system proceeds to  
20   step S30.

      At step S30, the CCU 28' is programmed to determine  
whether continued monitoring of the environment of the  
cabinet 14' is required. The CCU 28' is programmed to  
25   continuously monitor the sensors (T1,T2,T3,F1,F3) in an  
iterative loop as shown by step S31. The CCU 28'  
continues monitoring the sensors (T1,T2,T3,F1,F3) and  
performing steps (S2A,S2B,S3,S8,S19) until the  
environment management system 10' powers down.

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      The CCU 28' is programmed to ensure that the Rack  
Overheat light and Rack Shutdown light on indicator panel  
30 remains illuminated while any one of the measured  
sensor values (T1,T2,T3,F1,F2,P1) do not meet the

conditions defined above for set points (T1W,T2W,T3W,F1W,F2W,P1W,T1S,T2S,T3S,F1S,F2S,P1S). The Rack Overheat light is only turned off (ie reset) when all parameters obtain their normal operating conditions.

5

A set of exemplary set points for the set points tabulated in Table 1 are tabulated in Table 2 for the present disclosed embodiment. Table 2 also includes a set of preset values (T1R,T2R,T3R,F1R,F2R,P1R) for sensor value (T1,T2,T3,F1,F2,P1).

**Table 2**

| Set point | T1W<br>(°C) | T2W<br>(°C) | T3W<br>(°C) | P1W<br>psid | F1W%<br>max<br>rpm | F2W %<br>max<br>rpm |
|-----------|-------------|-------------|-------------|-------------|--------------------|---------------------|
|           | 22.5        | 40.9        | 38.1        | 0.276       | 70                 | 70                  |
| Set point | T1S<br>(°C) | T2S<br>(°C) | T3S<br>(°C) | P1S<br>psid | F1S<br>rpm         | F2S<br>rpm          |
|           | -           | 45.9        | 43.1        | -           | 55                 | 55                  |
| Set point | T1R<br>(°C) | T2R<br>(°C) | T3R<br>(°C) | P1R<br>psid | F1R<br>rpm         | F2R<br>rpm          |
|           | 20.5        | 38.9        | 36.1        | 0.350       | 85                 | 85                  |

The speed of the fan may range from 10,000 to 20,000 rpm depending on the diameter and types of fans. It should be noted that the maximum speed of the fan in Table 2 is about 20,000 rpm.

It will be appreciated that the values for the above set points are determined empirically from laboratory testing.

A second disclosed embodiment is described hereinafter. Fig. 3a shows a simplified perspective view of an environment management system 10. The system comprises a casing 100 having an air intake opening in the form of an inlet port 200 and an air exhaust opening in the form of an outlet port 400.

The casing 100 has a first side wall 110 (being the left end of the casing 100), a second side wall 120 (being the right end of the casing 100), a third side wall 130 (being the front end of the casing 100), a fourth side wall 140 (being the rear end of the casing 100), a bottom wall 150 and a top wall 160.

The inlet port 200 is positioned at the bottom wall 150 of the casing 100, where the port 200 links the casing 100 to a primary air moving unit in the form of fan 24. Fan 24 moves air at a first flow rate into the casing 100 via intake duct 32 and inlet port 200. Intake duct 32 is connected to a cold air source. An inlet orifice plate 220 is positioned inside the inlet port 200.

A plurality of electronic devices in the form of electronic cards 28 (refer to Fig. 4b) contained within electronic card cages (22,24,26) are arranged one on top of the other as shown in Figure 3b. The electronic card cage at the bottom is a first electronic card cage 22, the middle electronic card cage is a second electronic card cage 24, and the top electronic card cage is a third electronic card cage 26.

An air cooling module in the form of forced air cooling module 300 is also provided within the casing 100 and is mounted to a corner where the fourth side wall 140 and the first side wall 110 intersects. The air cooling module 300 comprises a primary duct 320, two secondary ducts (340,360), orthogonal to the primary duct 320, and a plurality of spray bars 380 mounted along the length of the secondary ducts (340,360).

A secondary air moving unit in the form of a suction fan 322 is provided in the primary duct 320. In use, the fan 322 moves cooling air at a second flow rate from the primary duct 320 through to the plurality of spray bars 380 so that cold air is sprayed directly onto the electronic cards 26 as heat is generated in use.

Primary duct orifice plates are installed within the primary duct 320 below each junction where the secondary ducts (340,360) intersect the primary duct 320. For instance, a first primary duct orifice plate 324 is attached below a first junction where the first secondary duct 340 intersects the primary duct 320. A second secondary duct orifice plate 326 is attached below a second junction where the second secondary duct 360 intersects the primary duct 320.

Figure 4a shows one mounting mechanism for mounting the electronic card cages (22,24,26) within the casing 100. A pair of support frames 500, 510 may be mounted onto a pair of opposing side walls, for instance, onto the first side wall 110 and the second side wall 120. Each support frame 500, 510 has a recess portion 520 and two projecting portions 540 and 560, wherein the recess portion 520 is between the projecting portions 540 and 560. The electronic card cage 20, as shown in Figure 4b, may have a protruding portion 21 on its opposing sides, wherein width of the protruding portion 21 is the width of the recess portion 520 of the support frames 500, 510. The electronic card cage 20 holds a plurality of electronic cards 28.

When slotted into the support frames 500, 510, the protruding portion 21 of the electronic card cage 22, 24 or 26 fits into the recess portion 520 of the support frames 500, 510. The first secondary duct 340 is in line with the base of the second electronic card cage 24, and the second secondary duct 360 is in line with the third electronic card cage 26. The spray bars 380 along the length of the first secondary duct 340 are positioned beneath the base of the second electronic card cage 24, and the spray bars 380 along the length of the second secondary duct 360 are positioned beneath the base of the third electronic card cage 26.

A perforated plate 600 having the same cross sectional area as the casing 100 is positioned between the forced air cooling module 300 and the inlet port 200. The volume of space between the inlet port 200 and the perforated plate 600 defines an air plenum 40. The perforated plate 600 has a first hole 620 and a second hole 640 cut into the plate 600. The first hole 620 is directly below the primary duct 320 of the forced air cooling module 300, and the second hole 640 is directly below the first electronic card cage 22.

The outlet port 400 is positioned at the top wall of the casing 100 to allow air that has been heated by the electronic card cages 22,24,26 to exit. The outlet port 400 could, for example, be a pipe (not shown) linking the casing 100 to the refrigeration package such that air that is heated by the electronic card cages 22,24,26 can be cooled and recycled for further use.

Two intake sensors T1 and F1 are provided adjacent to hole 640, while intake sensor P1 is provided adjacent

to hole 620. Two exhaust sensors T2, F2 are disposed between the secondary ducts (340,360) and one exhaust sensor T3 is provided adjacent to the outlet port 400. The sensors (T1,T2,T3,F1,F2,P1) function in exactly the same way as in the environment management system 10' as disclosed with reference to Fig. 1 above.

In this embodiment, a CCU 28 (not shown) functions according to the algorithm disclosed in Fig. 2 for the CCU 28' of environment management system 10'. The CCU 28 used to control the sensors (T1,T2,T3,F1,F2,P1). In the environment management system 10, however, the CCU 28 is not provided within the casing 100 but outside. The other difference with the environment management system 10 from system 10' above is that the sensors T2, F2, being mounted on fourth side wall 140 and between the secondary ducts (340,360), are able to provide a more enhanced alert to a user. For example, if the overheating occurs in electronic card cage 26, the sensor T2 does not indicate overheating while sensor T3 indicates overheating.

Accordingly, the CCU 28 can be programmed to determine if there is a variance with a particular sensor located throughout the casing 100 and can infer if a particular problem exists on a particular electronic card cage 26.

It will be appreciated that only a limited number of sensors (T1,T2,T3,F1,F2,P1), have been shown in Fig. 3a for illustrative purposes. Additional sensors disposed within the casing 100 could be used to identify overheating on particular electronic cards. Indeed, temperature sensors could be provided adjacent each spray

bar 380 to identify local overheating in particular electronic cards cage.

5 The environment management system 10 is particularly useful in an avionics upgrade program in which electronic racks are made redundant and are replaced by new electronic card cages (22,24,26). In such situations the new electronic card cages (22,24,26) have been found to dissipate a higher amount of heat than the electronic  
10 racks that were made redundant. Advantageously, the provision of spray bars allows cold air that has been boosted by the fan 322 to directly cool the electronic card cages (22,24,26) and overcome potential problems associated with inadequate cooling.

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The sensors (T1,T2,T3,F1,F2,P1) ensure that the forced air cooling module 300 functions effectively to adequately cool the electronic card cages (22,24,26). In particular, it will be appreciated that the environment  
20 management system 10 may be used to identify if the fan 322 has stopped working effectively due to sensors T2 and F2 or if there is a problem with the operation of the fan 24.

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### **Applications**

The environment management systems (10',10) can be used to monitor and thereby protect highly expensive electronic devices.

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The environment management systems (10',10) can be used to ensure that the electronic devices do not overheat by raising one or more alerts that the cooling system has failed or is inadequate. Advantageously, the alerts can be used to instruct an operator to shutdown

the electronic devices to prevent them from overheating in use.

Advantageously, the environment management system  
5 may automatically shutdown the operation of the electronic devices to prevent them from overheating in use.

It will be appreciated that the ability to  
10 simultaneously monitor more than one type of parameter of the cooling air (ie temperature, pressure, fan speed, relative humidity, smoke presence) provides additional redundancy should one of the sensors measuring a particular parameter fail. It will be appreciated that  
15 the multiple sensors complement each other because they measure multiple parameters of the air simultaneously.

Advantageously, because more than one parameter is monitored in the disclosed embodiments, overheating of  
20 the electronic devices may be more expedient. For example, if the fan fails, a lag time for an increase in the temperature of the cabinet (14') or casing (100). However, because the speed of the air within the cabinet (14') or casing (100) is also monitored, the CCU (28,28')  
25 can detect that the fan has failed and raise an alert. This allows evasive action and prevents damage to expensive electronic devices.

Additionally, because there is provision of the  
30 inlet and exit sensors, it is possible to determine if there is localised overheating within particular parts of the cabinet (14') or casing (100).

It will be apparent that various other modifications and adaptations of the invention will be apparent to the person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of  
5 the invention and it is intended that all such modifications and adaptations come within the scope of the appended claims.

## Claims

1. An environment management system for an electronic device, the environment management system  
5 comprising:

a casing having an air intake opening and an air exhaust opening, the casing capable of housing the electronic device, the electronic device capable of producing heat;

10 an air moving unit for moving air from the air intake opening, past the electronic device and to the air exhaust opening;

an exhaust sensor for detecting one or more parameters of the air after the air passes the electronic  
15 device; and

a controller electrically coupled to the exhaust sensor for receiving one or more signals representative of the detected one or more parameters of the air, the controller being responsive to the one or more signals to  
20 generate an alert in the event that one or more of the signals deviate from a predefined parameter range.

2. An environment management system as claimed in claim 1, further comprising an intake sensor electrically  
25 coupled to the controller, the intake sensor capable of detecting the one or more parameters of the air before the air passes the electronic device.

3. An environment management system as claimed in  
30 any one of the preceding claims, wherein the one or more parameters of the air are selected from the group consisting of: air temperature; air pressure; air speed; relative humidity; smoke presence; and air flow rate.

4. An environment management system as claimed in any one of the preceding claims, wherein the casing has a plurality of air intake openings.

5        5. An environment management system as claimed in any one of the preceding claims, wherein the casing has a plurality of air exhaust openings.

10       6. An environment management system as claimed in any one of the preceding claims, wherein a plurality of electronic devices are mounted within the casing.

15       7. An environment management system as claimed in claim 6, wherein a sensor is disposed between two adjacent electronic devices mounted within the casing.

20       8. An environment management system as claimed in any one of the preceding claims, wherein the air moving unit comprises one or more fans.

25       9. An environment management system as claimed in any one of the preceding claims, wherein the air is at a temperature in the range of about 5°C to about 18°C.

30       10. An environment management system as claimed in any one of the preceding claims, wherein the air is at a relative humidity in the range of about 20% to about 60%.

35       11. An environment management system as claimed in any one of claims 1 to 9, wherein the air is at a relative humidity in the range of about 30% to about 50%.

12. An environment management system as claimed in claim 2, wherein a plurality of air intake sensors are provided within the casing.

5        13. An environment management system as claimed in any one of the preceding claims, wherein a plurality of air exhaust sensors are provided within the casing.

10        14. An environment management system as claimed in any one of the preceding claims, wherein the alert generated by the controller indicates that the environment of the casing is at a temperature above a defined temperature.

15        15. An environment management system as claimed in any one of the preceding claims, wherein the alert generated by the controller indicates that the fan has stopped functioning.

20        16. An environment management system as claimed in any one of the preceding claims, further comprising a user interface to generate the alert.

25        17. An environment management system as claimed in claim 16, wherein the user interface is an indicator panel comprising one or more indicator lights thereon, the one or more indicator lights capable of illumination upon generation of the alert.

30        18. An environment management system as claimed in any one of the preceding claims, comprising an air cooling module mounted within the casing, the air cooling module comprising:

        a primary duct;

a plurality of spray bars in fluid communication with the primary duct; and

a secondary air moving unit for moving air, at a second flow rate, from the primary duct through to the plurality of spray bars;

wherein, in use, the spray bars spray cold air onto a plurality of the electronic devices.

19. A method of managing the environment of an electronic device disposed within a casing having an air intake opening and an air exhaust opening, the method comprising:

moving air past the electronic device;

detecting one or more parameters of the air after the air passes the electronic device;

monitoring the detected one or more parameters of the air; and

generating an alert when one or more of the detected parameters of the air deviates from a predefined parameter range.

20. A method as claimed in claim 19, comprising the step of:

detecting one or more parameters of the air before the air passes the electronic device.

21. An environment management system for an electronic device, the environment management system comprising:

a casing having an air intake opening and an air exhaust opening, the casing capable of housing a plurality of electronic devices, , the electronic devices capable of generating heat;

a primary air moving unit for moving air at a first flow rate through the air intake opening, into the casing and out through the air exhaust opening;

an air cooling module comprising a primary duct, a plurality of spray bars in fluid communication with the primary duct and a secondary air moving unit for moving air, at a second flow rate, from the primary duct through to the plurality of spray bars, the air cooling module being mounted within the casing such that, in use, the spray bars direct air onto the electronic devices;

at least one exhaust sensor for detecting one or more parameters of the air after the air has been sprayed onto the electronic devices; and

a controller electrically coupled to the exhaust sensor for receiving one or more signals representative of the detected one or more parameters of the air , the controller being responsive to the one or more signals to generate an alert in the event that one or more of the signals deviate from a predefined range.

22. An environment management system as claimed in claim 21, comprising one or more intake sensors for detecting the one or more parameters of the air before the air passes the one or more electronic devices.

23. An environment management system for an electronic device, the environment management system comprising:

a casing having an air intake opening and an air exhaust opening, the casing capable of housing the electronic device, the electronic device capable of producing heat;

an air moving unit for moving air from the air intake opening, past the electronic device and to the air exhaust opening;

5 one or more sensors for detecting two or more parameters of air within the casing; and

a controller electrically coupled to the one or more sensors for receiving signals representative of the detected two or more parameters of the air, the controller being responsive to the signals to generate an  
10 alert in the event that one of the two or more signals deviates from a predefined parameter range.

24. An environment management system, substantially as herein described with reference to the accompanying  
15 drawings.

25. A method of managing the environment of an electronic device disposed within a casing having an air intake opening and an air exhaust opening, substantially  
20 as herein described with reference to the accompanying drawings.