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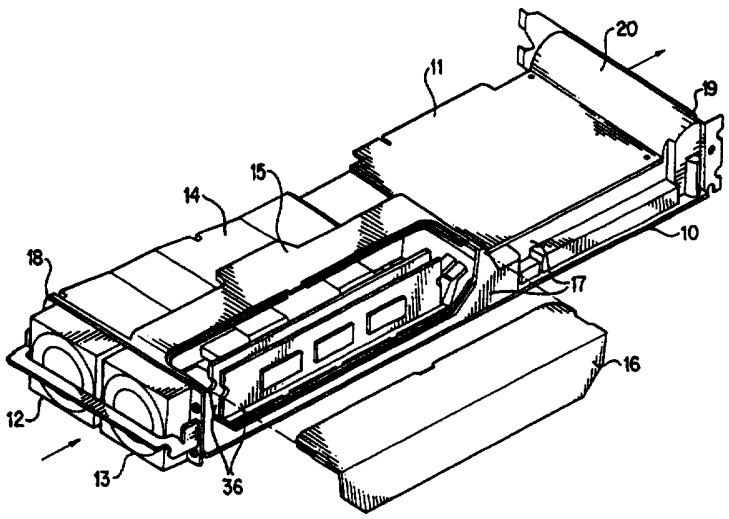


(57) Abstract

An active cooling arrangement for a removable circuit board (10) installed within a host computer, where the board has one or more components (31, 32) generating excessive heat, for which a duct defines an air-cooling path which includes the one or more components. The path has a duct (30) with an open side proximate to the circuit board so that the circuit board defines one boundary of the air-cooling path. An inlet (18) is provided for injecting cooled air onto the circuit board and an outlet (19) is provided for ejecting the air. The circuit board and the duct constitute an assembly. A fan or fans (12, 13) may be mounted on the assembly, and located so as to cause airflow along the path from the inlet to the outlet. The duct may have multiple constriction points (22, 23, 24, 25, 26, 27) near hot locations so that the cross-sectional area of the duct is variable along the air-cooling path, thus adjusting air velocity and heat transfer from components to the air. The duct may also be segmented into airflow regions having separate air-intake and fan arrangements (12, 13). Power may be reveived from the circuit board (29) or from an external power source (37), and the system may be formed from injection molded plastic.

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# Removable Circuit Board with Ducted Cooling

## FIELD OF THE INVENTION

The present invention generally relates to circuit boards having a cooling arrangement, and more particularly to actively cooled removable circuit boards for use in a computer.

## BACKGROUND OF THE INVENTION

Removable circuit boards have numerous components, including integrated circuits and other components that may consume substantial amounts of power. A component that consumes substantial amounts of power often generates an excessive amount of heat. Moreover, a specific component is designed to reliably operate within a certain temperature range. Therefore, if the temperature of a component exceeds that range, the component may not operate reliably, if at all. Such components are also known as hot components.

Previously, there have been two cooling systems used for removable circuit boards. The first cooling system provides the means for cooling only one component of the board at a time. This type of system provides site cooling. In site cooling, an individual fan is mounted on the heat sink to cool one component on the board. Using this type of cooling system for each hot component of a removable circuit board would be unduly bulky and inefficient.

The second type of cooling system provides a fan within a chassis, not on the board, to supply enough airflow through the chassis to cool all the components

in the chassis including any circuit boards. However, this type of system for cooling the components of a removable circuit board does not work for all board configurations. For example, hot components that have ball grid arrays instead of pins for mounting on a board present a special case. The reliability of that type of hot component is affected by stresses generated during the expansion and contraction of the components and the board due to temperature changes. Moreover, in order to get enough airflow in such a configuration, the size and type of chassis in which the removable circuit board is mounted must be considered. Thus, using this type of cooling system for some removable board configurations would be inadequate.

Another type of cooling system has been used for the (non-removable) mother board (CPU board) of a computer. This system uses a ducted design to provide cooled air to the critical components of the mother board. However, it is difficult to use such a system for cooling a removable circuit board.

Therefore, what is needed is a simple and compact system of cooling that efficiently provides cooled air to the components of a removable circuit board, independent of the size and type of chassis in which the circuit board is mounted.

## SUMMARY OF THE INVENTION

The present invention, in a preferred embodiment, is directed to an actively cooled removable circuit board that includes a circuit board having a connector along one end for connection to a mother board. The circuit board has one or more hot locations, i.e.,

locations for components that generate excessive heat. The present invention includes a duct for defining an air-cooling path wherein the path includes one or more hot locations. The air-cooling path is defined by the duct having an open side that is proximate to the circuit board so that the circuit board defines one boundary of the air-cooling path.

An inlet is provided for injecting cooled air onto the circuit board and an outlet is provided for ejecting the air. The circuit board and the duct constitute an assembly. Moreover, a fan is mounted on the assembly and the fan is located so as to cause airflow along the path from the inlet to the outlet.

The duct may be constricted in the vicinity of the hot locations such that the cross sectional area of the duct is variable along the air-cooling path. This allows the velocity of the airflow to increase near the hot locations which improves the heat transfer between components and the air.

The duct may be advantageously divided into multiple sections. The sections may be configured such that the airflow in one section does not mix or communicate with the airflow in the other sections. A section of the duct may have its own fan mounted to the assembly and located so as to cause airflow along the path defined by that section of duct. Moreover, a section of the duct may have its own inlet bringing air inside the chassis and its own outlet exhausting air outside the chassis.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a is an isometric view of an actively cooled

removable circuit board of a preferred embodiment of the present invention.

FIG. 1b is a top view of the configuration of the circuit board 10 of the embodiment of FIG. 1a.

FIG. 2a is a top sectional view of the embodiment of FIG. 1a illustrating the airflow path of a first embodiment of the duct of FIG. 1a.

FIG. 2b is a top sectional view of the embodiment of FIG. 1a illustrating the airflow path of a second embodiment of the duct of FIG. 1a.

FIG. 3a is a top view of a duct of the embodiment of FIG. 1a (reversed right and left).

FIG. 3b is a side view of the duct of FIG. 3a.

FIG. 3c is the other side view of the duct of FIG. 3a (reversed top and bottom).

## DETAILED DESCRIPTION OF THE DRAWINGS

Referring now to the drawings, FIG. 1a shows an actively cooled removable circuit board of a preferred embodiment of the present invention. A circuit board 10 is shown, forming the bottom surface of the embodiment of FIG. 1a. A second VGA circuit board 11 forms a portion of the top surface of the embodiment of FIG. 1a.

FIG. 1b shows a top view of the circuit board 10 which has numerous components mounted thereon. Resolvers 31 and Graphics Engine 32 are the hot components. Each of these hot components are associated with a hot location on the circuit board 10. Video Memory 33, RAMDAC 34, PCIDMA 35, and Texture Memory 36 are relatively cool components, i.e., consume relatively less power in comparison to Resolvers 31 and the

Graphics Engine 32. Circuit board 10 is supplied power via an edge connector 29 which connects to a mother board (not shown). Moreover, circuit board 10 is configured with pin connectors 37 for supplying power to fans 12 and 13 (shown in FIG. 1a).

The elements constituting a duct 30 of the present invention are shown in FIGS. 1a, 3a, 3b, and 3c. A top surface of circuit board 10, a bottom surface of VGA circuit board 11, a first top housing 14, a second top housing 15, a removable cover 16, a first side housing 17, an outlet housing 20, and a second side housing 21 define a duct 30. The duct 30 may include an inlet 18 and an outlet 19. Moreover, duct 30 defines an air-cooling path wherein the path includes the hot locations. The air-cooling path is transverse to a normal to an end of the edge connector 29.

The duct 30 and the circuit board 10 form an assembly to which fans 12 and fan 13 are mounted. In a preferred embodiment, the fans 12 and 13 are mounted to the assembly using a bracket and screws. Fans 12 and 13 are mounted at the inlet 18 so as to cause airflow along the path defined by duct 30. The airflow moves along the path defined by the duct 30 and is ejected or removed at the outlet 19.

In a preferred embodiment, duct 30 is divided into multiple sections (shown in FIG. 2a & 2b). In FIG. 2a, first section 40 of duct 30 overlies the Resolvers 31 (shown in FIG. 1b). The second section 41 of duct 30 overlies the Graphics Engine 32, the Video Memory 33, and the Texture Memory 36 (all shown in FIG. 1b). The third section 42 of duct 30 overlies the RAMDAC 34 and the PCIDMA 35 (both shown in FIG. 1b).

Referring now to FIGS. 1a and 2a, a first section 40 of duct 30 is defined by the first top housing 14, the second side housing 21, a first wall portion 44, a second wall portion 45, and a first area of the top surface of circuit board 10. The first section 40 of duct 30 receives a first airflow from fan 12.

The second section 41 of duct 30 is defined by the second top housing 15, the first side housing 17, the removable cover 16, the first wall portion 44, the second wall portion 45, and a second area of the top surface of circuit board 10. The second section 41 of duct 30 receives a second airflow from fan 13. When first wall portion 44 and second wall portion 45 are segmented (shown in FIG. 2a), then the air-cooling path of the first section 40 of duct 30 and the air-cooling path of the second section 41 of duct 30 are such that there is communication between the airflow in the first section 40 and the airflow in the second section 41 of duct 30. The communication is due to crossflow through an opening between first wall portion 44 and second wall portion 45.

Alternatively, when the first wall portion 44 and the second wall portion 45 are replaced by a continuous, solid wall 46 (shown in FIG. 2b), then there is no communication between the airflow in the first section 40 of duct 30 with the airflow in the second section 41 of the duct 30.

The third section 42 of duct 30 is defined by the bottom surface of the VGA board 11, the first side housing 17 and the second side housing 21. The third section 42 receives an airflow from the airflow of the first section 40 of duct 30 combined with the airflow of

the second section 41 of duct 30. The airflow in the third section 42 of duct 30 passes through the outlet section 43 of duct 30 before it is ejected at the outlet 19. In a preferred embodiment of FIG. 1a, the outlet section 43 of duct 30 is curved upward (as shown at 20 in Fig. 3b) so as to communicate with the outlet 19 for ejecting the airflow from the outlet section 43 of duct 30.

As air flows through the duct 30, the temperature of the air tends to increase due to the flow of air over hot locations. The duct 30 is preferably designed so that the components that are in the downstream airflow do not see excessive heat build-up from upstream components. Therefore, the cross sectional area of the duct 30 varies from the inlet 18 to the outlet 19.

The step-down reductions in the cross-sectional area of duct 30, shown in detail in FIGS. 3a and 3b, (as well as restrictions in Figs. 2a and 2b at A and B) tend to increase downstream airflow velocity. There are six step-down areas, 22, 23, 24, 25, 26, and 27 along first top housing 14. These step-down areas, increase the cooling effect near the vicinity of the hot locations because reducing the cross sectional area of the duct tends to increase the velocity of the airflow as it moves from the inlet 18 to outlet 19. Therefore, this step-down reduction in the cross sectional area of the duct 30 improves the heat transfer between the hot components and the air. Furthermore, it is preferred that the components which may be subject to a more rapid heat build-up are advantageously placed on the circuit board 10 such that they are near the inlet 18 and receive the initial and therefore coolest airflow.

Moreover, additional step-down reductions occur due to the restrictions at A and B (shown in Figs. 2a and 2b).

In a preferred embodiment, a portion of the duct 30 is injection molded plastic. Of course, it should be understood that various changes and modifications to the preferred embodiment described above will be apparent to those skilled in the art. For example, there may be only one fan with one section of duct. Furthermore, the duct could be mounted on the board or the fans could be mounted on the duct using a snap-lock mechanism instead of screws.

Therefore, these and other changes can be made without departing from the spirit and the scope of the invention and without diminishing its attendant advantages. It is therefore intended that such changes and modifications be covered by the following claims.

What is claimed is:

1. An actively cooled removable circuit board comprising:

a circuit board having a connector along one edge for connection to a mother board, said circuit board having one or more hot locations for components that generate excessive heat;

a duct mounted on the circuit board for defining an air-cooling path, said path including hot locations, the circuit board and the duct defining an assembly; and

a fan mounted to the assembly and located so as to cause airflow along the path.

2. The circuit board of claim 1 wherein the cross sectional area of the duct varies along the air-cooling path so as to increase the cooling effect in the vicinity of the hot locations.

3. The circuit board of claim 1 wherein the duct has an outlet section that is configured so as to eject air out of an outlet.

4. The circuit board of claim 2 wherein the duct has an outlet section that is configured so as to eject air out of an outlet.

5. The circuit board of claim 1 wherein the air-cooling path is defined by the duct having an open side that is proximate to the circuit board so that the circuit board forms one boundary of the air-cooling path.

6. The circuit board of claim 3 wherein the air-

cooling path is defined by the duct having an open side that is proximate to the circuit board so that the circuit board forms one boundary of the air-cooling path.

7. The circuit board of claim 4 wherein the air-cooling path is defined by the duct having an open side that is proximate to the circuit board so that the circuit board forms one boundary of the air-cooling path.

8. The circuit board of claim 1 wherein the duct comprises

a first section having a first air-cooling path with a first airflow;

a second section having a second air-cooling path with a second airflow, said second air-cooling path not being in communication with said first air-cooling path.

9. The circuit board of claim 8 wherein the first air-cooling path is not in communication with the second air-cooling path because of being separated by a wall.

10. The circuit board of claim 1 wherein the duct comprises

a first section having a first air-cooling path with a first airflow;

a second section having a second air-cooling path with a second airflow, said first air-cooling path being in communication with said second air-cooling path.

11. The circuit board of claim 10 wherein the

first air-cooling path is in communication with the second air-cooling path because of being separated by a segmented wall.

12. The circuit board of claim 9 wherein the duct further comprises a third section having a third air-cooling path, said third air-cooling path receiving its airflow from the first section of the duct and the second section of the duct.

13. The circuit board of claim 8 wherein the duct further comprises an outlet section that is configured so as to communicate with an outlet for ejecting the airflow from the third section of the duct.

14. The circuit board of claim 12 wherein the duct further comprises an outlet section that is configured so as to communicate with an outlet for ejecting the airflow from the third section of the duct.

15. The circuit board of claim 13 wherein the first and the second air-cooling paths are defined by the duct having an open side that is proximate to the circuit board so that the circuit board forms one boundary of the first and second air-cooling paths.

16. The circuit board of claim 14 wherein the first and the second air-cooling paths are defined by the duct having an open side that is proximate to the circuit board so that the circuit board forms one boundary of the first and second air-cooling paths.

17. The circuit board of claim 1 wherein the air-cooling path is transverse to a normal to the one edge.

18. The circuit board of claim 9 wherein the first and the second air-cooling paths are transverse to a normal to the one edge.

19. The circuit board of claim 11 wherein the first and second air-cooling paths are defined by the duct having an open side proximate to the circuit board so that the circuit board forms one boundary of the first and second air-cooling paths.

20. The duct of claim 19 further comprising a third section having a third air-cooling path, said third air-cooling path receiving its airflow from the first section of the duct and the second section of the duct.

21. The duct of claim 20 further comprising an outlet section that is configured so as to communicate with an outlet for ejecting the airflow from the third section of the duct.

22. A cooling system for a removable circuit board having a connector along one edge for connection to a mother board, said system comprising:

one or more hot locations on the removable circuit board for mounting components that generate excessive heat;

a duct mounted on the removable circuit board, the duct defining an air-cooling path; and

a first fan mounted on the duct for supplying airflow to the duct.

23. The system of claim 22 wherein the duct comprises

a first section having a first air-cooling path; and

a second section having a second air-cooling path, wherein the first air-cooling path and the second air-cooling path are not in communication.

24. The system of claim 23 wherein the first air-cooling path and the second air-cooling path are not in communication because of being separated by a wall.

25. The system of claim 22 wherein the duct comprises

a first section having a first air-cooling path; and

a second section having a second air-cooling path, wherein the first air-cooling path and the second air-cooling path are in communication.

26. The system of claim 25 wherein the first air-cooling path and the second air-cooling path are in communication because of being separated by a segmented wall.

27. The system of claim 23 further comprising a second fan mounted on the duct.

28. The system of claim 27 wherein the first fan

supplies airflow to the first section of the duct and the second fan supplies airflow to the second section of the duct.

29. The system of claim 25 further comprising a third section having a third air-cooling path for receiving the airflow from the first air-cooling path and the airflow from the second air-cooling path.

30. The system of claim 22 wherein the cross sectional area of the duct varies along the path so as to increase the cooling effect in the vicinity of the hot locations.

31. The system of claim 29 wherein the cross sectional area of the duct varies along the first and second air-cooling paths so as to increase the cooling effect in the vicinity of the hot location.

32. The system of claim 30 wherein the duct has an outlet section that is configured so as to eject airflow out of an outlet.

33. The system of claim 31 wherein the duct has an outlet section that is configured so as to eject airflow out of an outlet.

34. The system of claim 26 wherein the first and second air-cooling paths are defined by the duct having a first open side that is proximate to the removable circuit board so that the removable circuit forms one boundary of the air-cooling path.

35. The system of claim 29 wherein the first second and third air-cooling paths are defined by the duct having a first open side that is proximate to the removable circuit board so that the removable circuit forms one boundary of the first, second and third air-cooling paths.

36. The system of claim 30 wherein the air-cooling path is defined by the duct having a first open side that is proximate to the removable circuit board so that the removable circuit forms one boundary of the air-cooling path.

37. The system of claim 22 wherein the air-cooling path is transverse to a normal to the one edge of the removable circuit board.

38. The system of claim 35 wherein the duct further comprises a third section with a third air-cooling path for receiving the airflow from the first section and the airflow from the second section.

39. The system of claim 38 wherein the third air-cooling path is defined by the duct having a second partially open side that is proximate to a second circuit board so that the second circuit board forms a portion of a second boundary of the third air-cooling path.

40. The system of claim 35 wherein the third air-cooling path is defined by the duct having a second partially open side that is proximate to a second

circuit board so that the second circuit board forms a portion of a second boundary of the third air-cooling path.

41. The system of claim 36 wherein the air-cooling path is defined by the duct having a second partially open side that is proximate to a second circuit board so that the second circuit board forms a portion of a second boundary of the air-cooling path.

42. A cooling system for a removable circuit board having a connector along one edge for connection to a mother board mounted inside a chassis, said system comprising:

one or more hot locations on the removable circuit board for mounting components that generate excessive heat;

a duct mounted on the removable circuit board, the duct defining an air-cooling path; and

a first fan mounted on the duct for supplying airflow to the duct.

43. The system of claim 42 wherein the duct has an outlet section that is configured so as to eject airflow out of an outlet located to the exterior of the chassis.

44. A method for cooling a hot component having one or more hot locations on a removable circuit board comprising the steps of:

fitting a duct to the board to define an air-cooling path that includes the hot locations;

joining the board and duct to create an assembly; and

mounting a fan to the assembly to create airflow along the path.

45. The method of claim 44 wherein the step of fitting the duct comprises the step of

constricting the duct in the vicinity of the hot locations to increase the velocity of the airflow in the vicinity of the hot location so as to increase the cooling effect in the vicinity of the hot locations.

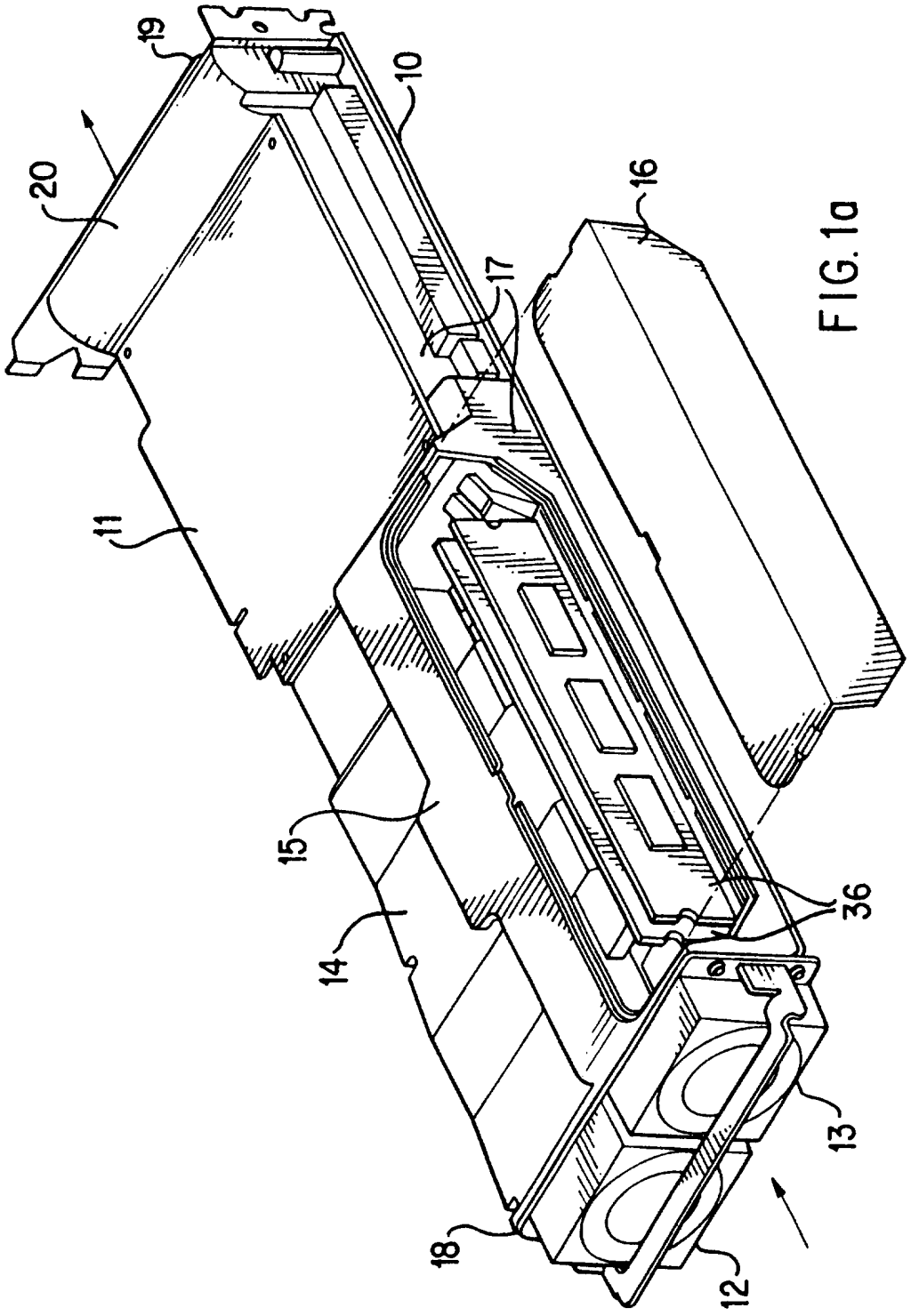



FIG. 1a

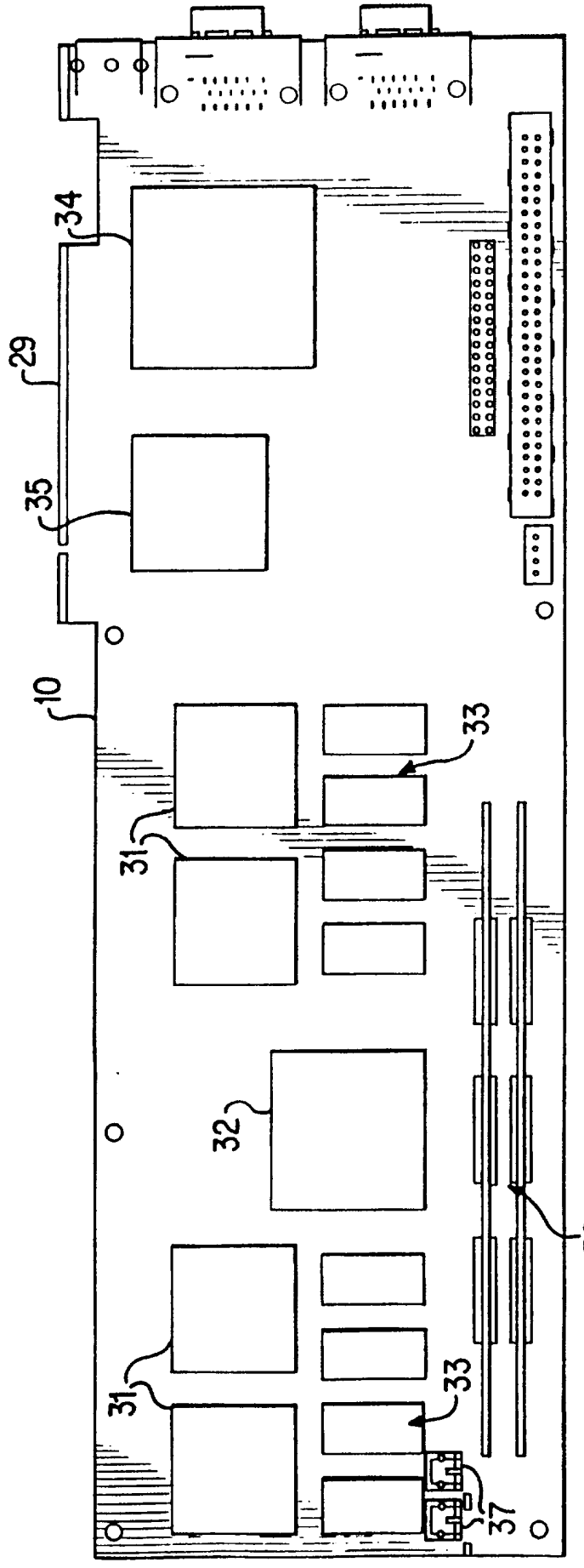
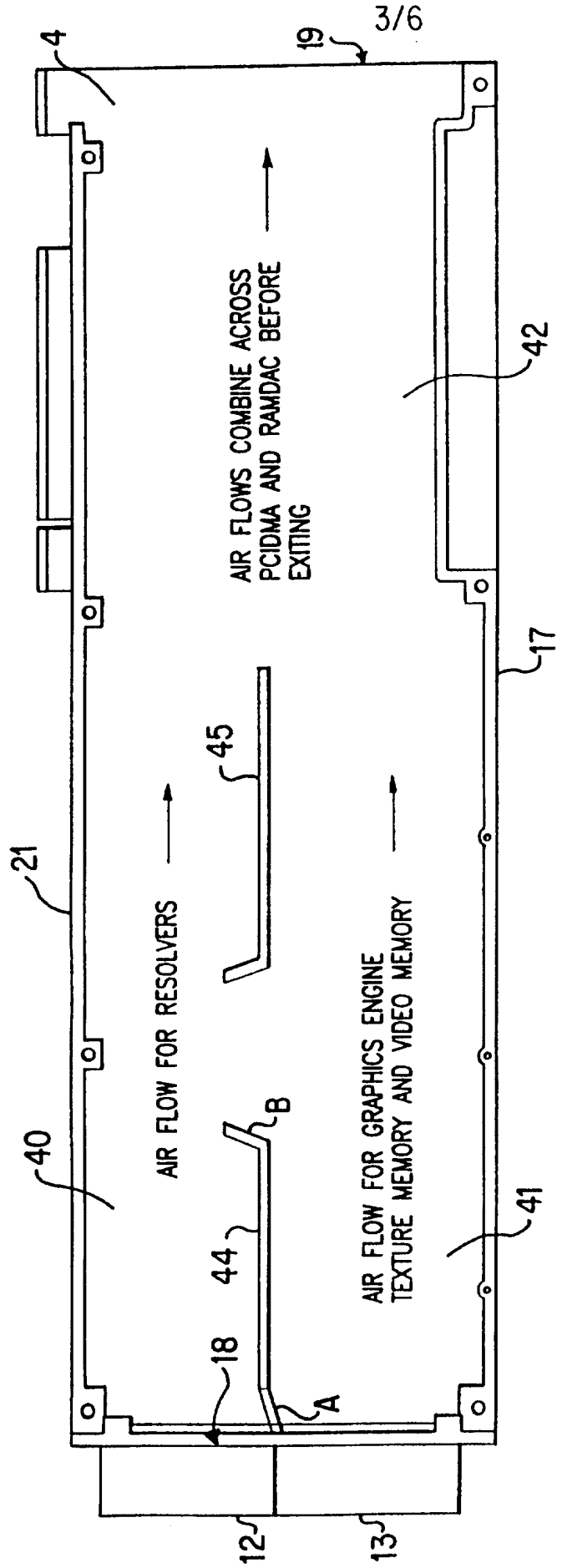



FIG. 1b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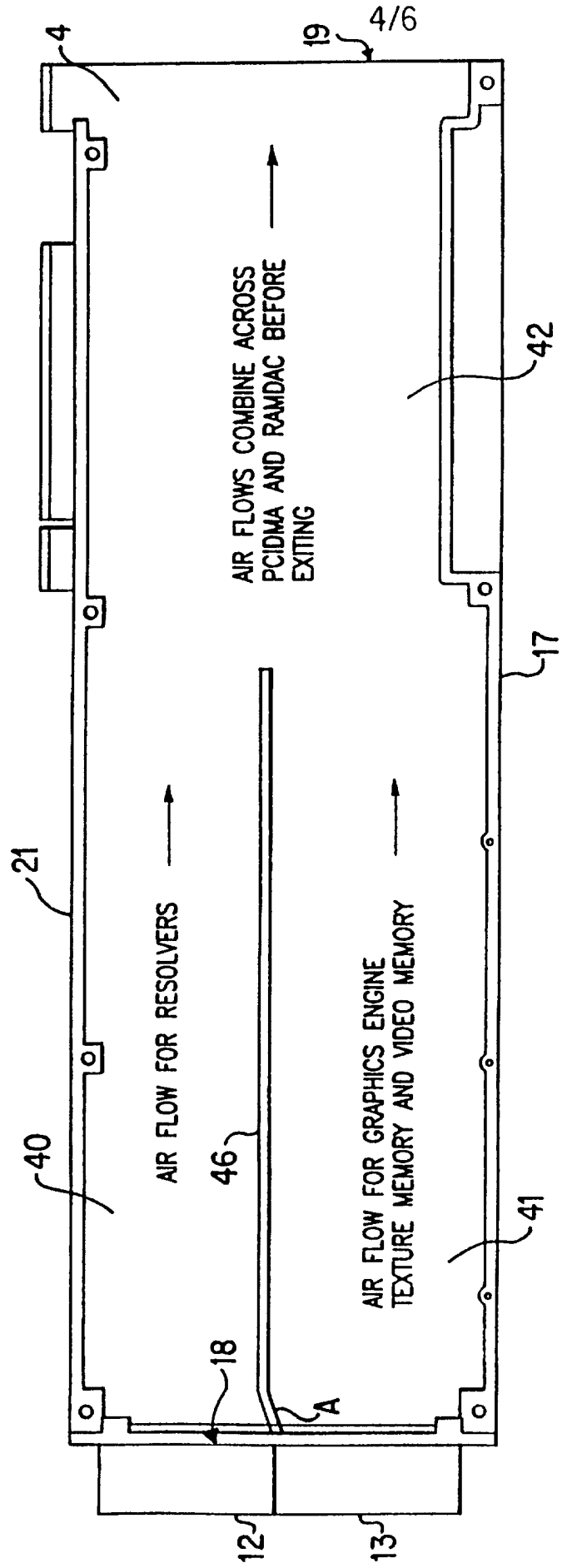
AIR FLOWS COMBINE ACROSS PCIDMA AND RAMDAC BEFORE EXITING
AIR FLOW FOR RESOLVERS
AIR FLOW FOR GRAPHICS ENGINE TEXTURE MEMORY AND VIDEO MEMORY

FIG. 2a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AIR FLOWS COMBINE ACROSS PCIDMA AND RAMDAC BEFORE EXITING
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AIR FLOW FOR GRAPHICS ENGINE TEXTURE MEMORY AND VIDEO MEMORY
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FIG. 2b

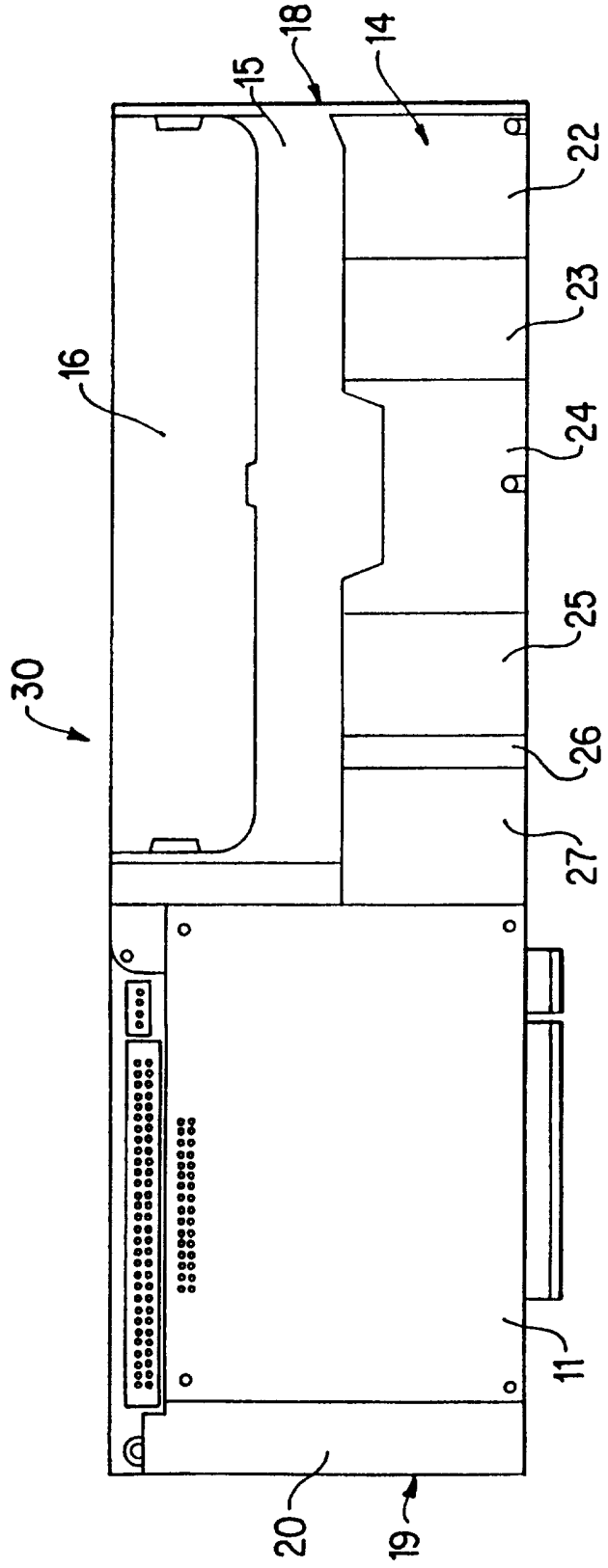


FIG. 3a

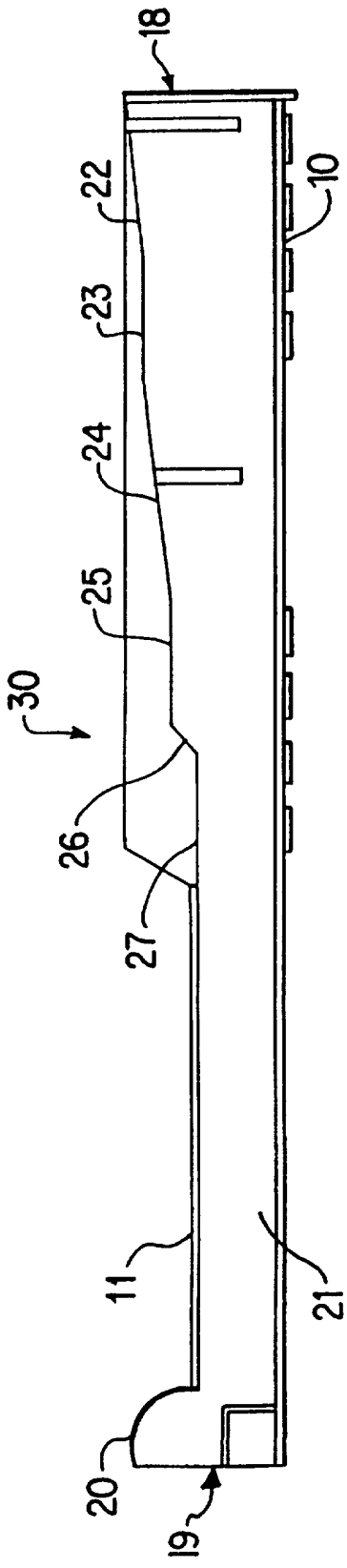


FIG. 3b

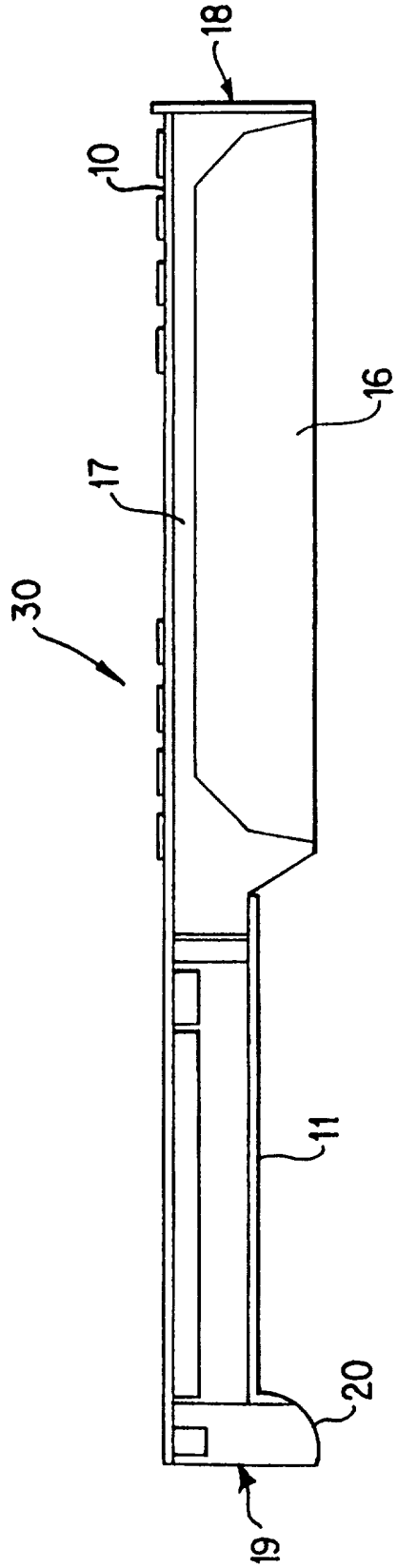


FIG. 3c

# INTERNATIONAL SEARCH REPORT

International Application No PCT/US 97/05949

A. CLASSIFICATION OF SUBJECT MATTER

H 05 K 7/20, H 02 B 1/00

According to International Patent Classification (IPC) or to both national classification and IPC6

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H 05 K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| X | EP, A, 0 614 330 (PFU) 07 September 1994 (07.09.94), all fig.; claims. | 1-45 |
| X | US, A, 4 797 783 (KOHMOTO) 10 January 1989 (10.01.89), fig.; abstract; column 3; claims. | 1-18, 22-24, 27-33, 42-44 |
| A | | 19-21, 34-41 |
| X | US, A, 4 837 663 (ZUSHI) 06 June 1989 (06.06.89), fig. 1,2,4; abstract; column 2, line 59 - column 3, line 66. | 1-7, 10,22, 42,44 |

[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

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Date of the actual completion of the international search

07 August 1997

Date of mailing of the international search report

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International Application No
PCT/US 97/05949

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## ANHANG

zum internationalen Recherchenbericht über die internationale Patentanmeldung Nr.

## ANNEX

to the International Search Report to the International Patent Application No.

## ANNEXE

au rapport de recherche international relatif à la demande de brevet international n°

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In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentdokumente angegeben. Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

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