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(54) Cooling of high voltage driver chips

(57) A compact cooling technique is provided for cooling an ink jet printer or printhead electronics. A cooling plate (18) is held in good thermal contact to the integrated circuits (12) to be cooled. Fluid passing through the cooling plate then cools the electronics. The cooling plate is typically an aluminum plate embedded with thin walled stainless steel tubing through which fluid flows to provide cooling. The cooling plate has a compliant pad (26) which is thermally conductive, and electrically insulated. The plate and pad combination is held against the integrated circuits for controlling the high voltage to the charging electrodes, which are mounted on the charge driver board. The integrated circuit is packaged in a cavity down ball grid array (BGA) package which provides low thermal resistance to the cooling plate. Variations in the height of the charge driver chips is compensated for by the compliant thermal pad. The fluid is routed through the printhead frame into the cold plate where heat is transferred to the fluid which returns to the printhead frame to exit the printhead. The fluid is ported into the printhead to where the drops will be generated.

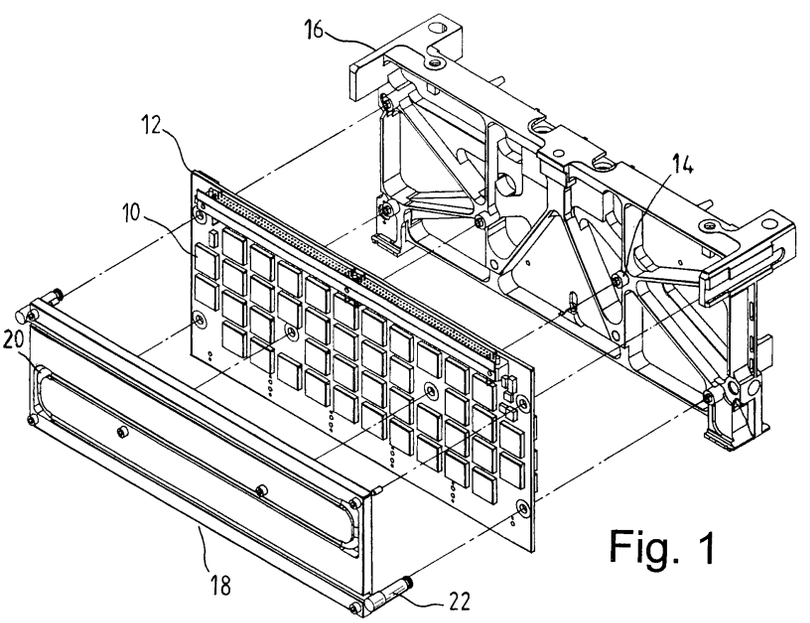

Fig. 1

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Description

Technical Field

[0001] The present invention relates to the field of continuous ink jet printing and, more particularly, to a cooling device for high power electronics utilizing the printing fluid in a continuous ink jet printer as the cooling medium.

Background Art

[0002] The printheads for long array, high resolution ink jet printers are customer replaceable units which contain the drop formation and selection components needed for printing, i.e., the drop generator, charge plate and catcher. To ensure reliability of the printhead, the printhead also includes a final ink filter. The charge driver switching electronics which controls the voltage to each charge plate electrode are also included in the printhead to minimize interconnect problems.

[0003] Printheads are required to be compact structures or assemblies that minimize parts usage, shipping and storage requirements, and provide a compact footprint on the paper transports upon which they print. One essential element of the printhead is the high voltage charge drivers. They are required to switch between 170 Vdc and 0 Vdc in ~1 μsec intervals. The load is essentially capacitive due to the parallel lead charge plate structure. Their power dissipation is proportional to the square of the switching voltage and linear with the switching frequencies. The printheads are required to print at high speeds which results in switching frequencies on the order of 100-300 kHz. These high switching frequencies, combined with the large number of charging electrodes for high resolution, long array printheads can result in a total power dissipation requirement for the charge drivers of up to 100 W in an area of approximately 48 square inches.

[0004] Common methods to remove heat from concentrated sources include fans, thermoelectric devices, and heat pipes. Fans are the standard method to transfer heat from components to the existing ambient but they require a large volume for the fan and the air routing. Thermoelectric devices require large heat sinks and high currents to pump the required heat away from the charge driver integrated circuit. Heat pipes are very efficient at removing heat from one point to another (similar to increasing the thermal conductivity of the material), however, they still require large heat sinks. These methods for cooling the charge drivers, with large sinks and air flow volumes, are all incompatible with the need for a small printhead.

[0005] It is seen, then, that there exists a need for a cooling means which overcomes the problems associated with cooling means of the prior art.

Summary of the Invention

[0006] This need is met by the cooling device of the present invention wherein cooling of the high power electronics, such as high voltage driver chips, is accomplished utilizing the fluid (ink) used for printing.

[0007] In accordance with one aspect of the present invention, a cooling apparatus comprises a cooling plate held in good thermal contact to the integrated circuits to be cooled. Fluid passing through the cooling plate then cools the electronics. The cooling plate consists of an aluminum plate embedded with thin walled stainless steel tubing through which fluid flows to provide cooling. The cooling plate has a compliant pad which is thermally conductive, and electrically insulated. The plate and pad combination is held against the integrated circuits for controlling the high voltage to the charging electrodes, which are mounted on the charge driver board. The integrated circuit is packaged in a cavity down ball grid array (BGA) package which provides low thermal resistance to the cooling plate. Variations in the height of the charge driver chips is compensated for by the compliant thermal pad. The fluid is routed through the printhead frame into the cold plate where heat is transferred to the fluid which returns to the printhead frame to exit the printhead. The fluid is then ported into the drop generator.

[0008] Other objects and advantages of the invention will be apparent from the following description, the accompanying drawing and the appended claims.

Brief Description of the Drawing

[0009]

Fig. 1 is an exploded view of a printhead showing the cooling plate, charge driver board and printhead frame; and

Fig. 2 is a side view showing the compliant pad pressed in contact with the integrated circuits.

Detailed Description of the Preferred Embodiments

[0010] Referring to Fig. 1, the present invention proposes a charge driver cooling system using the fluid in a continuous ink jet printer as the cooling medium. As indicated, the charge driver electronics 10 are attached to one side of a printed circuit board 12. The board serves to route the leads from the individual driver packages to the connectors that mate to the charge plate leads. The high voltage integrated circuits have been packaged in Ball Grid Array (BGA)packages with the cavity down. These packages, which thermally sink the integrated circuit die to an exposed thermally conductive metal plate, provide low thermal resistance to the heat sink. The printed circuit board is mounted to standoffs pads 14 machined onto the printhead frame 16.

[0011] Mounted to the same side of the printhead

frame is a cooling plate 18. As seen in Fig. 2, an electrically insulating, high thermal conductivity complaint pad 26, such as Berquist Gap Filler VO, is sandwiched between the driver circuits 10 and the cooling plate. This pad insures good thermal contact between the driver circuits and the aluminum plate. As both the cooling plate and the circuit board are mounted to standoff pads machined onto the same structure, the gap between the integrated circuits and the cooling plate can be well defined. In this way, proper compression and therefore thermal conduction through the compliant pad can be ensured. The compliant pad has sufficient compliance to account for small variations in gap between the integrated circuits and the cooling plate, caused by variations in IC thickness or warpage of the circuit board.

[0012] The cooling plate 18 comprises an aluminum heat exchange plate with embedded with thin walled stainless steel tubing 20 and an associated fluid port 22. A mating fluid port 24 is associated with the printhead frame 16. Cooling fluid passes through the tubing 20 to carry heat away from the cooling plate and the heat generating electronics. The fluid tubing can be attached and thermally linked to the heat exchange plate by any suitable means such as welding, adhesive bonding or by hydraulically expanding the tubing in the routing grooves of the heat exchange plate.

[0013] In accordance with one embodiment of the present invention, the most compact form of heat exchanger for this application is a cold plate circulating a cooling fluid. The cooling plate could comprise the evaporator stage of a refrigerant based heat exchanger. Such a cooling loop would typically require extra pumps, filters, fluids, tubing , etc. just to support this function. A more attractive option is to use the ink jet fluid system to provide the cooling fluid to the cooling plate. The ink used for printing would also then serve to cool the printhead electronics. With an ink flow rate as low as 100 ml/min, the cool plate can provide the necessary cooling to the electronics while only heating the ink by 14C. The cool plate can be routed either in parallel or in series with the printhead. That is one could route the ink so that some ink goes through the cool plate and then back to the ink tank while the bulk of the ink goes to the printhead. Otherwise one could route the ink so that it all passes through the cool plate on its way to the drop generator. The second option is preferred as it lowers the flow rate requirements for the fluid system. In systems where the ink temperature is to be controlled to improve the ink jet functionality, it is desirable to monitor the ink temperature after the cooling plate. Then the temperature control servo can adjust the temperature of the ink supplied to the cooling plate to maintain the desired temperature of the ink entering the drop generator.

[0014] The invention has been described in detail with particular reference to certain preferred embodiments thereof, but it will be understood that modifications and variations can be effected within the spirit and scope of the invention.

Claims

1. An ink jet printer having compact means for cooling the printer or printhead electronics comprising:

   a circuit board having high voltage drivers mounted on at least one side thereof;
   a cooling plate;
   means for routing cooling fluid through the cooling plate;
   a thermally conductive compliant pad to ensure thermal contact between the cooling plate and the high voltage drivers; and
   a means for holding the thermally conductive compliant pad and cooling plate against the circuit board.

2. An ink jet printer as claimed in claim 1 wherein the cooling fluid comprises ink.

3. An ink jet printer as claimed in claim 1 further comprising pumping means to pump the cooling fluid.

4. An ink jet printer as claimed in claim 3 wherein through the pumping means comprises an ink jet printhead fluid system.

5. An ink jet printer as claimed in claim 1 wherein the cooling plate comprises a thermally conductive plate having fluid tubes securely attached and thermally coupled thereto.

6. A cooling apparatus for cooling high power electronics in an ink jet printing system comprising:

   a cooling plate;
   routing means associated with the cooling plate to route a cooling fluid;
   a compliant pad between the cooling plate and the high power electronics for providing thermal conductivity; and

7. A cooling apparatus as claimed in claim 6 further comprising a means for holding the compliant pad and the cooling plate against the high power electronics.

8. A cooling apparatus as claimed in claim 6 wherein the cooling fluid comprises ink.

9. A cooling apparatus as claimed in claim 6 wherein the cooling plate comprises a thermally conductive plate having fluid tubes securely attached and thermally coupled thereto.

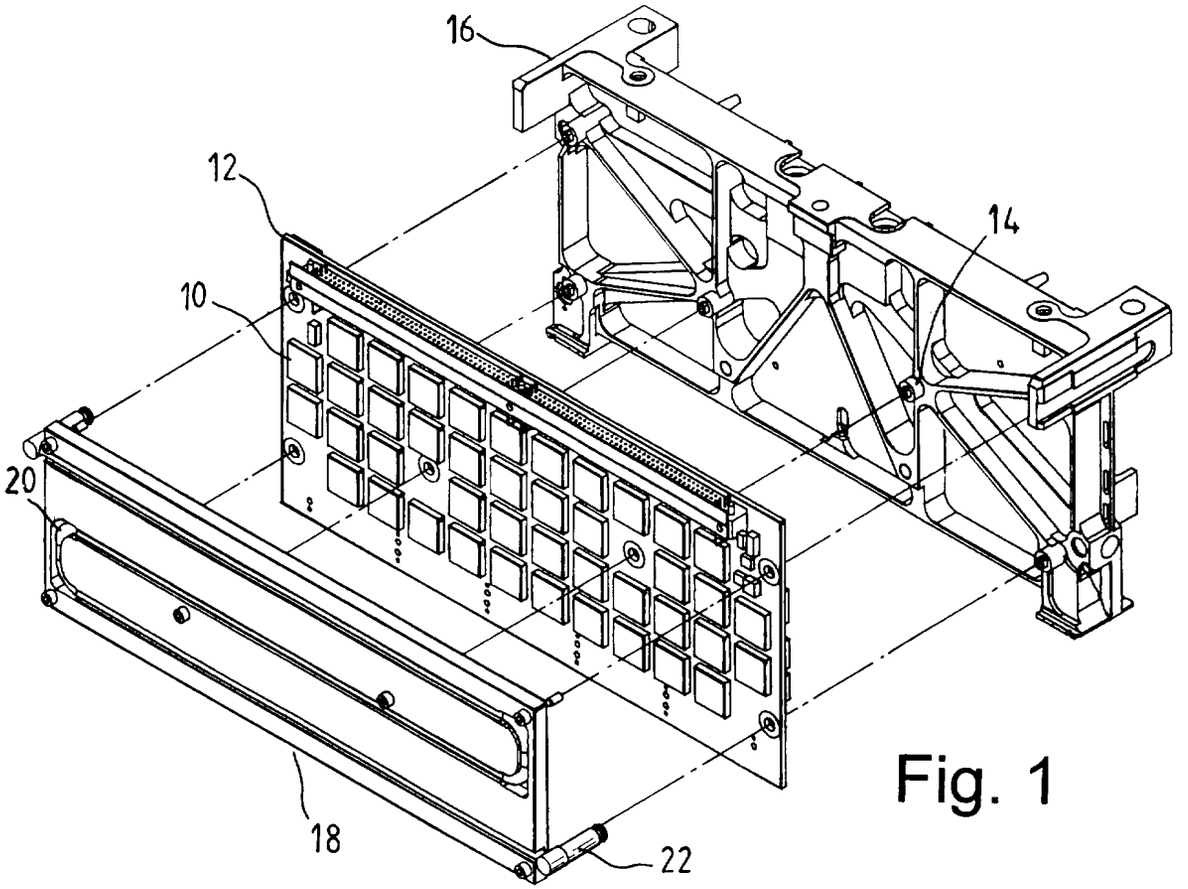

Fig. 1

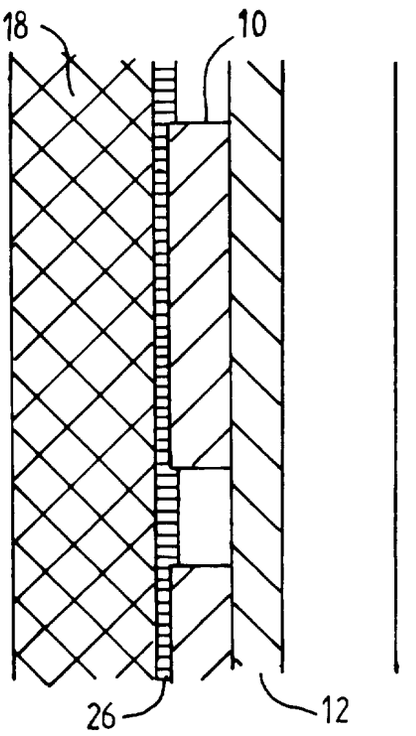

Fig. 2