Technology Review:

Compliant Cold Plates, 1991-2007

Qpedia continues its review of technologies developed for electronics cooling applications. We are presenting selected patents that were awarded to developers around the world to address cooling challenges. After reading the series, you will be more aware of both the historic developments and the latest breakthroughs in both product design and applications. We are specifically focusing on patented technologies to show the breadth of development in thermal management product sectors. Please note that there are many patents within these areas. Limited by article space, we are presenting a small number to offer a representation of the entire field. You are encouraged to do your own patent investigation. Further, if you have been awarded a patent and would like to have it included in these reviews, please send us your patent number or patent application.

In this issue our spotlight is on compliant cold plates. There is much discussion about its deployment in the electronics industry, and these patents show some of the salient features that are the focus of different inventors.

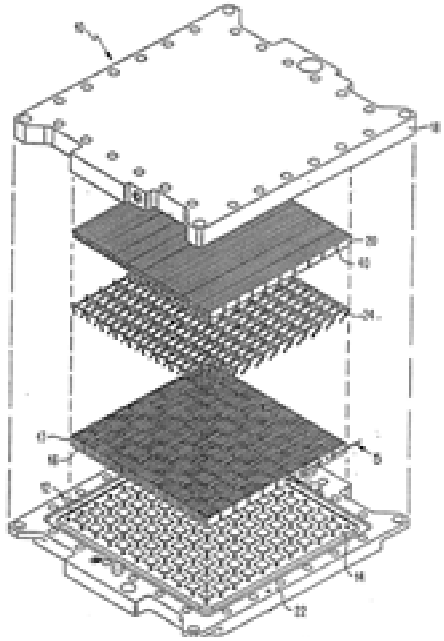
HIGH CONDUCTION FLEXIBLE FIN COOLING MODULE

0454603A2, Horwath, J.

This invention relates to conduction cooling of small, flat, heat generating devices such as integrated circuit (IC) chips, and more particularly, to an improved cooling device having a very low thermal resistance path between the heat generating devices and heat sink.

The introduction of large scale integration (LSI) and very large scale integration (VLSI) at the chip level and very large scale integration at the module level by packaging multiple chips on a single multilayer substrate has significantly increased both circuit and power densities. As a consequence, there arises the need to remove heat flux densities on the order of 1000kw/square meter at the chip level. To remove these high heat flux densities, there have been proposed various means of dissipating the heat. One limitation is that the cooling fluid (e.g., water) cannot come into direct contact with the chips or the area wherein the chips are mounted.

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
0454603A2	HIGH CONDUCTION FLEXIBLE FIN COOLING MODULE	Horwath, J. et al.	Feb 21, 1991
US 6111749	FLEXIBLE COLD PLATE HAVING A ONE-PIECE COOLANT CONDUIT AND METHOD EMPLOYING SAME	Lamb, R., et al.	Sept 29, 2000
US 7298618B2	COOLING APPARATUSES AND METHODS EMPLOYING DISCRETE COLD PLATES COMPLIANTLY COUPLED BETWEEN A COMMON MANIFOLD AND ELECTRONICS COMPONENTS OF AN ASSEMBLY TO BE COOLED	Campbell, L., et al.	Nov 20, 2007



Thus, a cooling hat must be incorporated between the chips and fluid which may be contained in a detachable or integral cold plate.

As VLSI chips increase in circuit density, switching speed and corresponding power, the thermal resistance of heat conduction systems, wherein an internal thermal device insert is placed between the chips and cooling hat, must be further reduced. In the thermal conduction module of Chu et al. U.S. A n° 3.993.123, the internal thermal device insert is a piston which contacts the chip at one point. The thermal conduction module is very useful and successful in VLSI systems of the present but is not easily extendable to future high powered systems in all applications.

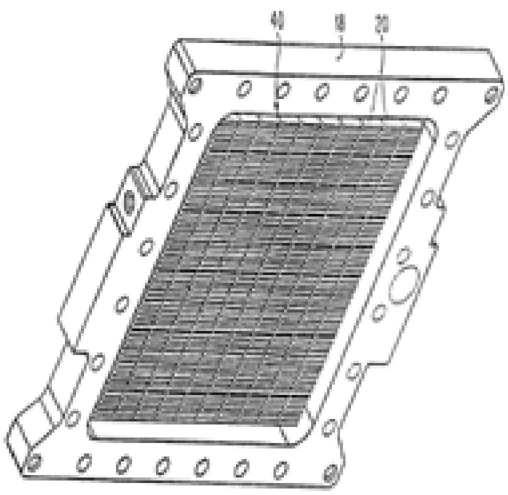
In the present state of the art there are many structures for achieving enhanced heat transfer. Among these are intermeshed fin structures wherein the internal thermal device insert has substantially rigid fins which mate with corresponding fins in the cooling hat. One such fin structure is that disclosed in Horvath et al. E.P. A n° 344 084, the disclosure of which is incorporated by reference herein. These structures have the potential to provide improved thermal performance over single-surface structures, such as the piston in the thermal conduction module, because they comprise means for increasing the heat transfer area between the internal thermal device insert, which contacts the chip, and the cooling hat. Consequently, the thermal resistance between the chip and the cooling hat is lowered.

An inherent feature of these substantially rigid fin structures is that there will always be a gap, sometimes relatively large, between the intermeshed fins to accommodate chip tilt. This gap may be compensated by side-biasing or by filling the gap with a compliant, thermally conductive medium such as disclosed in Horvath et al. While such a fin structure does provide a low thermal resistance, the thermal resistance of the structure may be decreased by decreasing or, more preferably, substantially eliminating this gap.

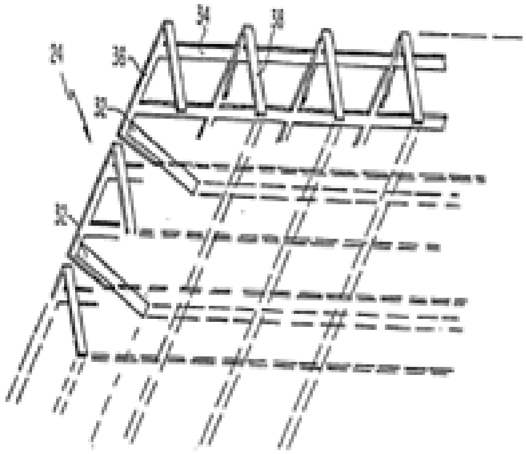
An alternative structure has been proposed in Mansuria et al. U.S. A n° 4.263.965 wherein a plurality of thermally conductive thin leaf shaped members are positioned within mating recesses of a cooling hat. Each of the thin leaf shaped members is independently spring-loaded against the chip. Chip tilt is accommodated at the chip-to-leaf interface. Thus, this design often times results in line-contact of the thin leaf shaped members against the chip, leading to a decrease in thermal efficiency of the module. Further, and perhaps most importantly, the leaf shaped members, while being thin, are nevertheless rigid as are the mating recesses of the cooling hat. Due to manufacturing tolerances, there will always be a considerable gap between the leaf shaped members and the cooling hat, thereby contributing to increased thermal resistance. It has been proposed in certain structures to make the fins out of a flexible material. Thus, in Lipschutz U.S. A n° 4.498.530, a plurality of flexible leaf elements are sandwiched between rigid spacer elements. The end result is a relatively rigid package, which is placed between the chip and the cold plate. Due to the fact that the flexible elements do not make good thermal contact with their corresponding flexible elements, the thermal resistance of this arrangement is unacceptably high. Also, since the entire structure is separate and distinct from the cold plate, an additional thermal resistance (i.e., arising from the interface between the cold plate and the structure) is included.

Tinder U.S. A n° 4.707.726 discloses a heat sink having a channel therein and a plurality of semiconductor devices which are positioned within the channel. The semiconductor devices are side-biased against the side of the channel by a flexible member.

Berg U.S. A n° 4.447.842 discloses a thermal device in contact with a chip. The thermal device has flexible fins which fit into channels of a cooling module. The cooling module is fitted with an expansible conduit which, upon expansion, causes the flexible fins to be forced against the sides of the cooling module, thereby aiding in the cooling of the chip.



In the most preferred embodiment, when biasing means 24 is present, the biasing means will reside in channels 28. The biasing means 24 urges the thermal device insert toward the chip to apply a desired pressure against the chip, thereby assuring good thermal contact with the chip. It is possible to make the biasing means separable so that each thermal device insert will have its own biasing means, separate and apart from every other biasing

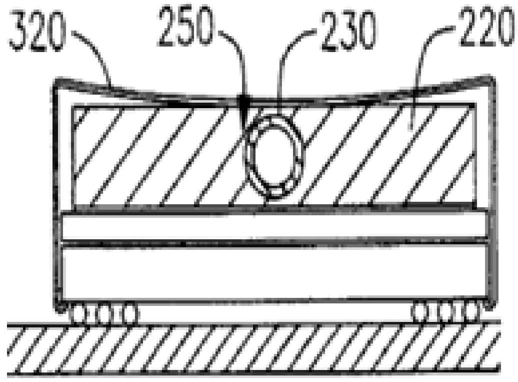


means. It has been found preferable, however, to make the biasing means so that a plurality of individual biasing means are connected together. The biasing means 24 has cantilever arms 32 which reside in channels 28. The cantilever arms 32 urge the thermal device inserts into contact with the chips. Individual biasing means are connected by longitudinal supports 34 which also reside within channels 28. If it were desirable to have more than one row of biasing means or more than one cantilever arm per chip site, then crosspiece 36 is necessary to connect longitudinal supports 34. Crosspieces 36 reside within channels 40 of the flexible second fins 20.

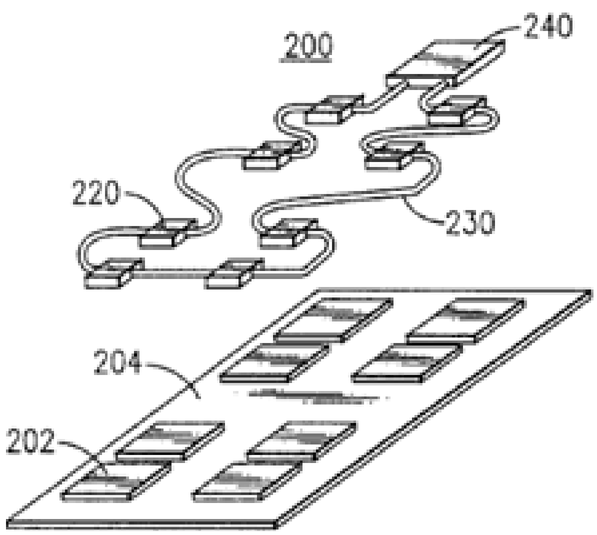
FLEXIBLE COLD PLATE HAVING A ONE-PIECE COOLANT CONDUIT AND METHOD EMPLOYING SAME

US 6111749, Lamb, R., et al.

The complex design of integrated circuits today contribute to the increased circuit density of the chips utilized. However, as the chip density increases, the thermal properties of the circuit package becomes an important concern. The ability to remove heat generated from the high-powered and highly dense integrated circuits in a semi-conductor packaging becomes vital to the function and performance of the electronics. The initial approach taken to cooling electrical



devices through the use of air convection has been replaced by water cooling methods. As the density and integration level of these circuits increases, the amount of heat dissipated by the system can no longer be adequately removed through the use of conventional air convection techniques. Furthermore, the physical size of an effective air convection heat sink is prohibitive, a main concern when using compact devices such as lap-top computers.



Indirect water cooling approach using cold plates quickly has become a selected approach to eliminate the large amount of heat generated by the high power semiconductor modules on large size PC boards or cards. Nonetheless, indirect water cooling approach has not eliminated all heat removal concerns, particularly when a direct or immersion cooling approach is used.

The geometry of the circuit board and its modules has contributed to new concerns, compounding the heat removal problems. Often an array of electronic modules are mounted on a flat printed circuit board. The modules may be of different shapes and geometry and therefore, the height of a particular module can be much higher or lower than that of its neighbors. Due to a large variance of card flatness and module heights, a misalignment of module top surfaces can lead to a complicated set of problems affecting module powers, uneven thermal resistance and even solder failures caused by mechanical stress applied to the joints.

Accordingly, an object of the present invention is to provide an apparatus and method for cooling electronic devices able to accommodate a variety of geometric constraints.

Another object of the present invention is to provide an apparatus for uniform cooling of electronic devices able to accommodate the cooling of all components or modules regardless of location, while taking into account the misalignment of chip surfaces.

Yet another object of the present invention is to provide an apparatus and method for cooling electronic devices with an improved thermal performance and reliability feature.
A further object of the present invention is to provide a low cost alternative to electronic cooling devices.

To achieve the above-mentioned objects, and other related ones, a method and apparatus for cooling electronic devices is suggested comprising of a thermally conductive, flexible, non-jointed cooling conduit able to house a coolant. The conduit is passed or pulled through holes provided on a plurality of cold plates. The conduit and plate arrangement is then placed in thermal communication with the electronic device or assembly to be cooled. The flexibility of the conduit allows the conduit with plates to be rearranged in X-Y or Z axis orientation as to complement the

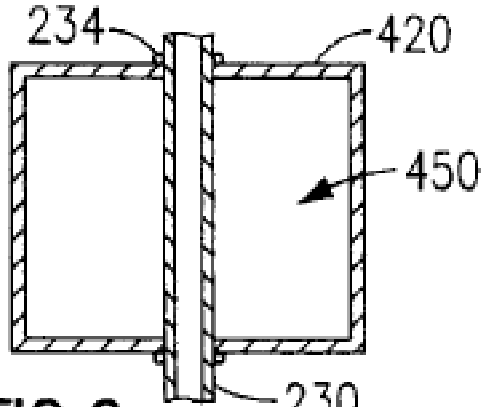


FIG.6

contour of the device to be cooled. This rearranging of the conduit provides for thermal conductivity improvements between the device and the conduit with plates.

In one embodiment of the present invention, the electronic device to be cooled is an electronic assembly housing modules. The cold plates are further individually secured to the modules to provide maximum cooling.

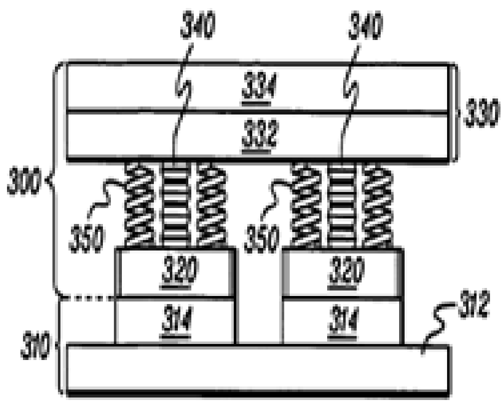
In either design, solder or securing means 234 or alternate attachment methods can then be used to fix the conduit more securely to the plates, before or after putting the plate-conduit arrangement in thermal communication with the device and the components to be cooled.

COOLING APPARATUSES AND METHODS EMPLOYING DISCRETE COLD PLATES COMPLIANTLY COUPLED BETWEEN A COMMON MANIFOLD AND ELECTRONICS COMPONENTS OF AN ASSEMBLY TO BE COOLED

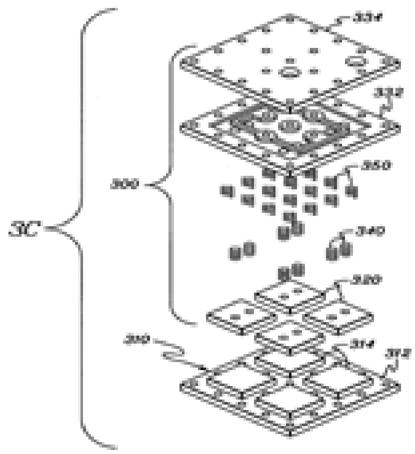
US 7298618B2, Campbell, L., et al.

A cooled electronics system comprising cooling apparatus 300 coupled to an electronics assembly 310 for facilitating cooling thereof, in accordance with an aspect of the present invention. As shown, cooling apparatus 300 includes multiple discrete and rigid cold plates 320, each of which couples to a respective electronics component 314 disposed on a support structure 312. Each electronics component is a heat generating component, and as noted, may comprise a multichip module, single-chip module, or one or more unpackaged circuit die, etc., while structure 312 may comprise a planar board, stiffener or other rigid substrate.

Cold plates 320 are rigid structures to facilitate thermal interface of each forced cold plate and its respective electronics component. Coolant is fed to cold plates 320 in parallel from a common, rigid manifold 330 through compliant flexible hoses 340. In this example, manifold 330 includes a rigid lower manifold portion 332 and a rigid upper manifold portion 334, between which appropriate inlet and outlet plenums are defined, as described further below. A biasing mechanism, such as a plurality of springs 350, is disposed between the multiple cold plates 320 and the manifold 330 to bias the cold plates away from the manifold, and towards the electronics components 314, thereby ensuring good thermal interface between the cold plates and the electronics components, notwithstanding variation in height or angular orientation of the components relative to their support structure.



An upper manifold portion 334 has a single coolant inlet 335 and a single coolant outlet 337. In this embodiment, a plurality of holes 339 are also provided which extend through the manifold and at least partially into the support structure to allow for one or more fasteners to secure the cooling apparatus to the support structure of the electronics assembly.



A cooling apparatus 300 is located above electronics assembly 310. In this example, electronics assembly 310 includes support structure 312 and a 2×2 array of electronics components 314 requiring cooling. As noted, cooling apparatus 300 includes: multiple cold plates 320, each of which has at least one coolant inlet, at least one coolant outlet and at least one coolant channel for the flow of coolant there through; compliant flexible hoses 340, which provide a fluid-tight connection between the common manifold and the individual cold plates 320 while maintaining freedom of motion for the cold plates; and multiple springs 350, with four springs per cold plate. Springs 350 are sized to provide a desired force against cold plates 320 to ensure a favorable thermal contact between each cold plate and its respective electronics component, as well as provide cold plate compliance which allows the components to vary in height and/or orientation within the electronics assembly. The common distribution manifold again includes, in this embodiment, lower manifold portion 332 and upper manifold portion 334 which are configured to seal together and define between them at least one inlet plenum and at least one outlet plenum. This manifold distributes coolant to the coolant inlets of the multiple cold plates and receives coolant from the coolant outlets of the multiple cold plates.

Each manifold portion is designed with a similar interfacing relief structure, which together define a single inlet plenum 331 and a single outlet plenum 333. Coolant is fed through a single coolant inlet 335 in upper manifold portion 334 and is distributed to the cold plates via multiple cold plate coolant inlets 341 (and the flexible hoses) in fluid communication with inlet plenum 331. Similarly, outlet plenum 333 exhausts heated coolant through a single coolant outlet 337, and is in fluid communication with multiple cold plate coolant outlets 342, through which coolant is received from the cold plates.