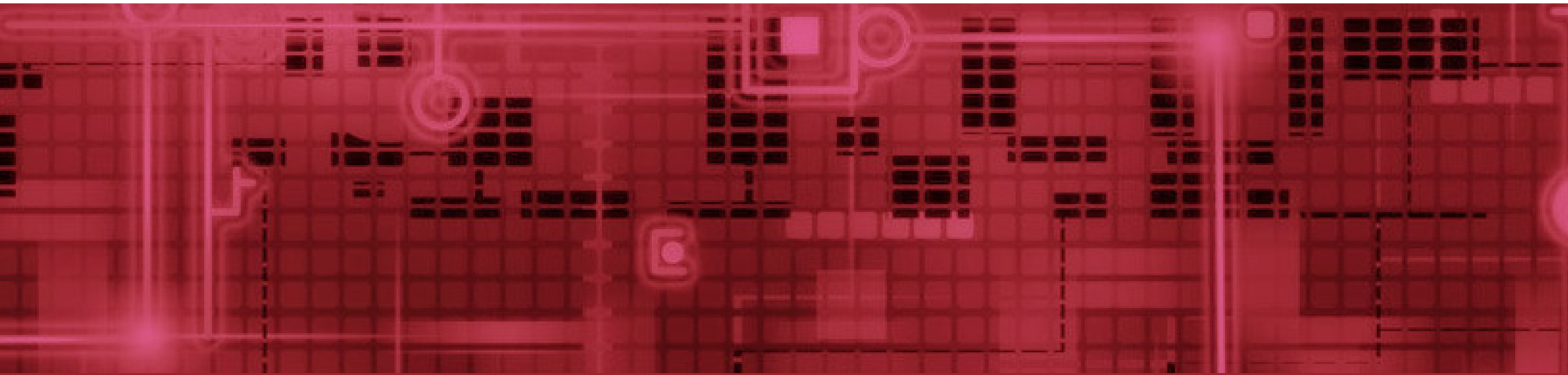


Technology Review

Cold Plates, 2001 to 2003

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 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.

COLD PLATE ARRANGEMENT FOR COOLING PROCESSOR AND COMPANION VOLTAGE REGULATOR

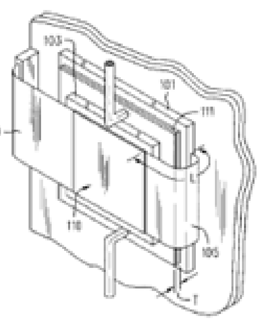
6,191,945 B1, Belady, C., et al.

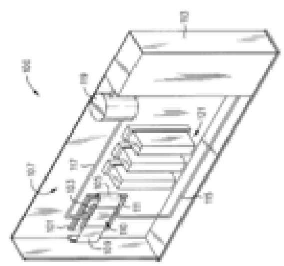
A compact cooling method and apparatus arranged for simultaneously drawing heat from both a processor and from the voltage regulator. The invention provides for advantageous arrangement of the voltage regulator and memory proximate to the processor for high speed operation. The invention includes a processor requiring at least one bias voltage, and further includes a companion voltage regulator for providing the bias voltage. The voltage regulator is arranged sufficiently proximate to the processor, so as to limit inductance of electrical coupling there.

The invention provides an efficient and compact cooling method and apparatus arranged for simultaneously drawing heat from both a processor and from the voltage regulator, while still providing for advantageous arrangement of the voltage regulator and memory proximate to the processor for high speed operation.

PATENT NUMBER	TITLE	INVENTORS	DATE OF AWARD
6,191,945 B1	COLD PLATE ARRANGEMENT FOR COOLING PROCESSOR AND COMPANION VOLTAGE REGULATOR	Belady, C., et.al.	Feb. 20,2001
6,351,381 B1	HEAT MANAGEMENT SYSTEM	Bilski, J., et.al.	Feb. 26, 2002
6,519,955 B2	PUMPED LIQUID COOLING SYSTEM USING A PHASE CHANGE REFRIGERANT	Marsala, J.	Feb. 18, 2003

In the past, bulky cooling mechanisms have interfered when designers have pursued a substantially co-planar arrangement of the processor and voltage regulator extending across the surface of a motherboard. In contrast, the present invention provides a compact stack arrangement of voltage regulator, cold plate and processor, each advantageously arranged proximate to one another for high speed operation. The proximate arrangement also provides advantages in reduction of electrical noise (as well as corresponding reduction in requirements for use of decoupling components such as capacitors and the like.)





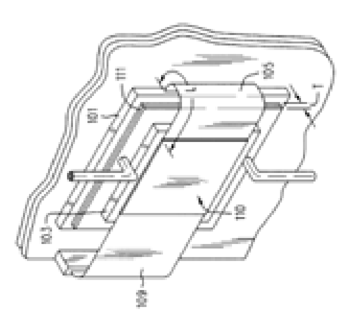
Briefly and in general terms the invention includes a processor requiring at least one bias voltage, and further includes a companion voltage regulator for providing the bias voltage. Electrical coupling between the voltage regulator and the processor conducts the bias voltages thereto. The voltage regulator is arranged sufficiently proximate to the processor, so as to limit inductance of the electrical coupling there between.

At least one cold plate is sandwiched between the processor and the voltage regulator in thermal communication therewith, and is arranged for simultaneously drawing heat from the processor and from the voltage regulator.

The invention further provides for electrical coupling between a memory and the processor, for conducting signals there between. The memory is arranged sufficiently proximate to the processor, so as to limit propagation delay of the signals through the electrical coupling, so as to provide for the high speed operation.

The invention includes a processor 101 requiring at least one bias voltage, and further includes a companion voltage regulator 103 for providing the bias voltage. Electrical coupling 105 between the voltage regulator and the processor conducts the bias voltages. Preferably the electrical coupling 105 includes a strip of single or multilayer polyimide (or polyester) based flexible printed circuit material. There are some trade-offs to be made. Although multilayer strips may provide a desirable lower inductance, they are generally more expensive than single layer strips. A source voltage is provided to the voltage regulator 103 from a supportive printed wiring board 107 through another electrical coupling 109, preferably also of the flexible printed circuit material. A square fixture of printed wiring board 110 is soldered to the voltage regulator 103 and to each of the electrical couplings 107, 109 of flexible printed circuit material, so as to provide secure electrical connection thereto. Alternatively, a so called "flying lead" may be used for connecting said another electrical coupling 109.

A cold plate 111 is sandwiched between the processor 101 and the voltage regulator 103 in thermal communication therewith, and is arranged for simultaneously drawing heat from the processor and from the voltage regulator. A heat exchanger 113 is thermally coupled in fluid communication with the cold plate for drawing heat therefrom. The invention includes a pair of fluid conduits 115, 117 coupled with the flow paths of the cold plate 111 and the heat exchanger 113 for circulating the fluid there between. In the preferred embodiment, the fluid conduits are made from quarter inch (or half inch) diameter hollow copper tubing, or another suitable material.



The cold plate 111 has a first and second opposing major surface. The voltage regulator 103 has a major surface in thermal communication with the first major surface of the cold plate 111. The processor 101 has a major surface in thermal communication with the second opposing major surface of the cold plate 111. The cold plate should be large enough for thermal coupling with the processor and voltage regulator, and furthermore should be large enough to provide for coupling to the fluid conduits. For example, in the case the major surface of the processor having width and depth dimensions of approximately three (3) inches by approximately five (5) inches, it is preferred that each of the opposing major surfaces of the cold plate have width and depth dimensions of approximately (3.75) inches by approximately (5.75) inches.

HEAT MANAGEMENT SYSTEM

6,351,381 B1 , Bilski, J., et. al.

The present invention provides a heat management system for controlling the temperature inside of at least one cabinet containing a plurality of electronic systems and components.

In a preferred embodiment of the invention, a first heat exchange assembly is provided that includes at least one cold plate that is thermally interconnected with at least one of the electronic systems and components. A channel is defined in the cold plate that supports a tube having an entrance opening, an exit opening, and is arranged to be in confronting relation to a portion of the electronic systems and components so as to form a passageway for a liquid coolant fluid to travel through the channel in thermal communication with the portion of the electronic systems and components.

A second heat exchange assembly is provided that includes a condenser arranged in fluid flow communication with the entrance opening and the exit opening of the tube and a plurality of fans arranged in confronting relation to the condenser.

A third heat exchange assembly is provided that includes at least one stack of substantially parallel plates arranged in two-plate assemblies.

Each two-plate assembly has a closed end and an open end such that a closed end of one two-plate assembly is sandwiched between an open end of two adjacent two-plate assemblies. At least two fans are provided, with one fan arranged so as to: (i) blow air onto a portion of the plurality of electronic systems and components, (ii) draw heated air away from a portion of the plurality of electronic systems and components, and (iii) blow the heated air into the open ends of the two-plate assemblies. Another fan supplies cooler, ambient air to the adjacent two plate assembly to remove the heat and vent it outside of the cabinet through a side wall.

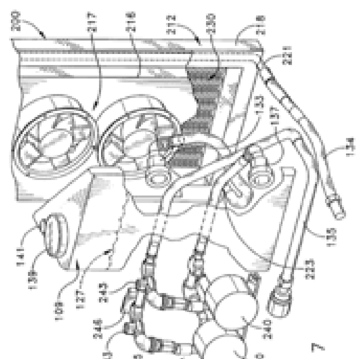
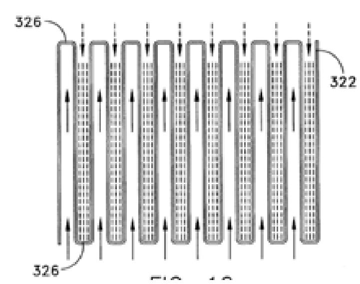
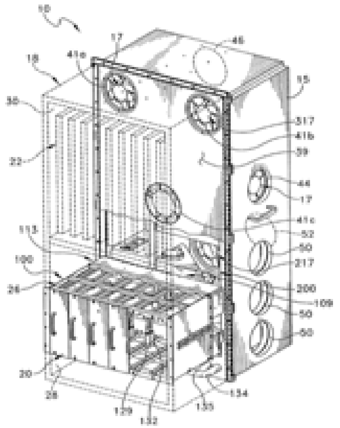


FIG. 7



A thermal management system 10 formed in accordance with the present invention comprises a primary heat exchange assembly 100, a secondary heat exchange assembly 200, and a tertiary heat exchange assembly 300. Secondary and tertiary heat exchange assemblies 200 and 300 are housed in a first cabinet 15 which is attached to a portion of a second electronic systems cabinet 18, e.g., a CDMA systems cabinet. Electronic systems cabinet 18 houses various heat generating electronic systems and devices, e.g., one or more LPA amplifiers and associated electronics modules 20 and one or more communications control systems and radio units 22. Several electronics modules 20 are supported in each of a plurality of racks 26 which are mounted, side-by-side, within a



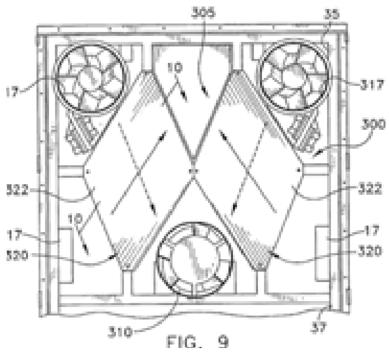


FIG. 9

bottom portion 28 of electronic systems cabinet 18. Plurality of radio units 22 are mounted within a top portion 30 of electronic systems cabinet 18.

Cabinets 15 and 18 comprise generally rectilinear structures that are arranged so as to thermally communicate with one another, via thermal management system 10. More particularly, cabinet 15 comprises an upper compartment 35 and a lower compartment 37 that house secondary and tertiary heat exchange assemblies 200 and 300, respectively.

A hinged panel 39 operates to close-off both upper compartment 35 and lower compartment 37. Hinged panel 39 includes three openings 41a, 41b, and 41c in a top portion which allow for the only fluid communication between the interior of upper compartment 35 of cabinet 15 and top portion 30 of electronic systems cabinet 18. The walls of cabinet 15 that bound upper compartment 35 include side wall openings 44 and a rear wall opening 46.

Lower compartment 37 is sized and shaped to house secondary heat exchange assembly 200. A plurality of openings50 are defined through the side walls of cabinet 15 so as to provide for flow communication of air into lower compartment 37 and rear wall opening 52 provides for flow communication of air out of lower compartment 37. The compartments of cabinet 15 are typically sealed by welding or application of a sealant to maintain separation between them and the ambient environment.

A pair of coolant transport conduits 106 are positioned on the outer surface of each cold plate 103, on the side opposite to the channel, and are shielded by a cover 107. One conduit 106 is connected to open end 111 of tube 104 at entrance port 124 and one conduit 106 is connected to open end 112 of tube 104 at exit port 126. Coolant fluid ports 128,130 are each disposed at an open end of a coolant transport conduit 106, and are sized and shaped to interconnect with a distribution manifold 113, via connectors 129,132, and there through to hoses 134,135 that together guide the circulation of coolant fluid 127 between tubes 104 in each of cold plates 103 and coolant reservoir 109. Typically, the heat removed by primary heat exchange assembly 100 is approximately 4,500 watts, with cold plates 103 maintaining 80° C at the outer surface of each electronics module housing, and with the entire system operating at +50° C ambient temperature.

Thus, a first two-plate assembly allows air to flow between its plates, but not to enter further into the interior of cabinet 15. Likewise, a second adjacent two-plate assembly allows air to flow between its plates, but not to exit the interior of cabinet 15. As a result, outside ambient air is circulated through air-to-air heat exchanger 305 by fans 17 located in side wall openings 44, while air from the interior of cabinet 15 is circulated through air-to-air heat exchanger 305 via fans 317 located in openings 41a and 41b of wall 39, and reintroduced into electronics cabinet 18 via blower 310 located in opening 41c. This arrangement prevents the exchange of outside ambient air with air disposed within the lower compartment 37 of cabinet 15. Tertiary heat exchange assembly 300 operates in such a way that a maximum 15° C temperature rise inside the enclosure is experiment, J.

PUMPED LIQUID COOLING SYSTEM USING A PHASE CHANGE REFRIGERANT

6,519,955 B2, Marsala, J.

This need is met by the pumped liquid cooling system of the present invention wherein cooling is provided to electrical and electronic components with very low parasitic power consumption and very high heat transfer rates away from the component surface. This invention also reduces the temperature drop required to move heat from the component to the ambient sink.

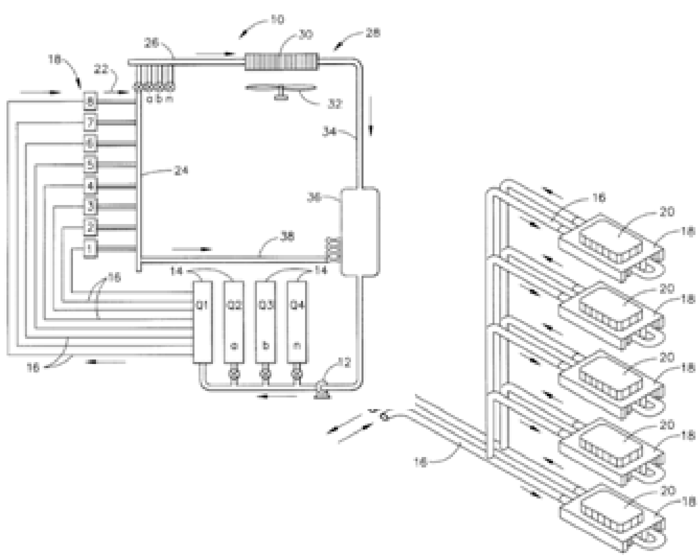
In accordance with one aspect of the present invention, a liquid refrigerant pump circulates refrigerant to cold plate/evaporators which are in thermal contact with the electrical or electronic component to be cooled. The liquid refrigerant is then partially or completely evaporated by the heat generated by the component. The vapor is condensed by a conventional condenser coil, and the condensed liquid, along with any unevaporated liquid, is returned to the pump. The system of the present invention operates nearly isothermally in both evaporation and condensation.

Accordingly, it is an object of the present invention to provide cooling to electrical and electronic components. It is a further object of the present invention to provide such cooling to components with very low parasitic power consumption and very high heat transfer rates away from the component surface. It is yet another object of the present invention to reduce the temperature drop required to move heat from the component to the ambient sink.

There is a cooling system 10 which circulates a refrigerant as the working fluid. The refrigerant may be any suitable vaporizable refrigerant, such as R-134a. The cooling cycle can begin at liquid pump 12, shown as a Hermetic Liquid Pump. Pump 12 pumps the liquid phase refrigerant to a liquid manifold 14, where it is distributed to a plurality of branches or lines 16. Additional liquid manifolds 14a, 14b and 14n are shown to indicate where more branches (or lines) could be attached. The actual 30 number of branches will depend on the number of components to be cooled by the system. From the manifold 14, each branch or line 16 feeds liquid refrigerant to a cold plate 18.

Each cold plate 18 is in thermal contact with an electrical or electronic component or components 20 to be cooled, causing the liquid refrigerant to evaporate at system pressure. None, some, or all of the liquid refrigerant may evaporate at cold plate 18, depending on how much heat is being generated by component 20. In most cases, some of the refrigerant will have evaporated and a two-phase mixture of liquid and vapor refrigerant will leave each cold plate 18, as shown by arrow 22.

The vapor/liquid separator 24 is attached to a vapor line 26 leading to condenser 28, comprised of a condensing coil 55 and a fan 32. Additional vapor/liquid separators 24a, 24b,and 24n, may be connected through the use of vapor manifolds so that the cooling capacity of the system may be increased. Condenser coil 30, attached to vapor line 26, condenses the vapor phase back to a liquid and removes the heat generated by the electronic components 20. Although it will occur to those skilled in the art that any suitable form of heat rejection may be used without departing from the scope of the invention, such as an air cooled condenser, a water or liquid cooled condenser, or an evaporative condenser.



The condenser 28 operates at a pressure which corresponds to a temperature somewhat higher than the temperature of the ambient air. In this way, it is impossible for condensation to form, since no system temperature will be below the ambient dew point temperature. The condenser operating point sets the pressure of the entire system by means of the entering coolant temperature and its ability to remove heat from the condenser, thus fixing the condensing temperature and pressure. Also, since vaporized refrigerant is being condensed to a liquid phase, the condenser 28 sets up a flow of vaporized refrigerant from the vapor/liquid separator 24 into the condenser 28, without the need for any compressor to move the vapor from the cold plate evaporator 18 to the condenser 28. The liquid refrigerant exits the condenser 28, as indicated by arrow 34, and moves by gravity to a liquid receiver 36, which holds a quantity of liquid refrigerant.

Unlike the pumped liquid single-phase system, the present invention operates isothermally, since it uses change of phase to remove heat rather than the sensible heat capacity of a liquid coolant. This allows for cooler temperatures at the evaporator and cooler components than a single phase liquid system. Low liquid flow rates are achieved through the evaporation of the working fluid to remove heat, keeping the fluid velocities low and the pumping power very low for the heat removed. Parasitic electric power is reduced over both the pumped single-phase liquid system and the vapor compression refrigeration system.

An advantage over the heat pipe system is obtained with the system 10 of the present invention because the liquid fow rate does not depend on capillary action, as in a heat pipe, and can be set independently by setting the flow rate of the liquid pump. Dry out can thus be avoided. The cold plate/evaporator system of the present invention is insensitive to orientation with respect to gravity. Unlike heat pipe systems, the thermal capacity of the evaporator 18 of the present invention does not diminish in certain orientations.

Another advantage of the present invention over heat pipe and vapor compression based systems is the ability to separate the evaporator and condenser over greater distances. This allows more flexibility in packaging systems and design arrangements. In accordance with the present invention, liquid and vapor are transported independently, allowing for optimization of liquid and vapor line sizes.

The present invention easily handles variation in thermal load of the components 20 to be cooled. Since any unevaporated liquid refrigerant is returned to the pump, multiple cold plates at varying loads are easily accommodated without fear of damaging a compressor. Since the current invention does not operate at any point in the system 10 at temperatures below ambient dew point temperature, there is no possibility of causing water vapor condensation and the formation of liquid water.