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(56) Documents cited

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(58) Field of search
F4U

(54) Heat sink arrangement

(57) A cooling arrangement for a thyristor (1) is in the form of a finned metallic heat sink and includes a chamber (11-14) which constitutes an isothermal region. By minimising the temperature drop across this region heat transfer to the more remote surface areas of the heat sink is greatly improved. The isothermal region takes the form of a heat pipe or thermosyphon, or a part thereof. Conveniently, the chamber is formed as an integral part of an extruded aluminium alloy, and contains a quantity of a volatile liquid, e.g. pentane.

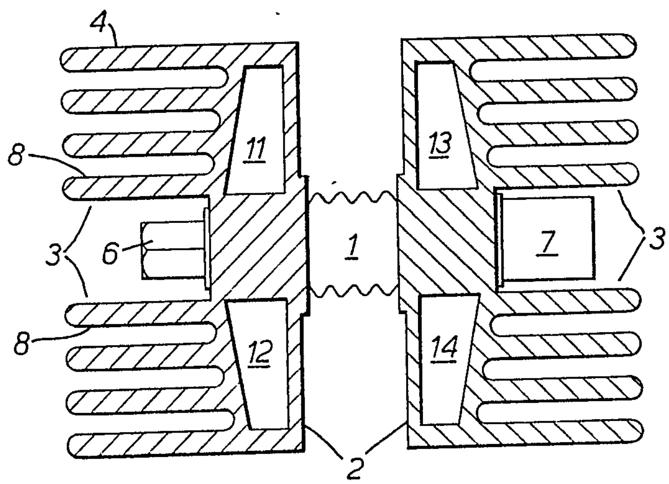

FIG. 1.

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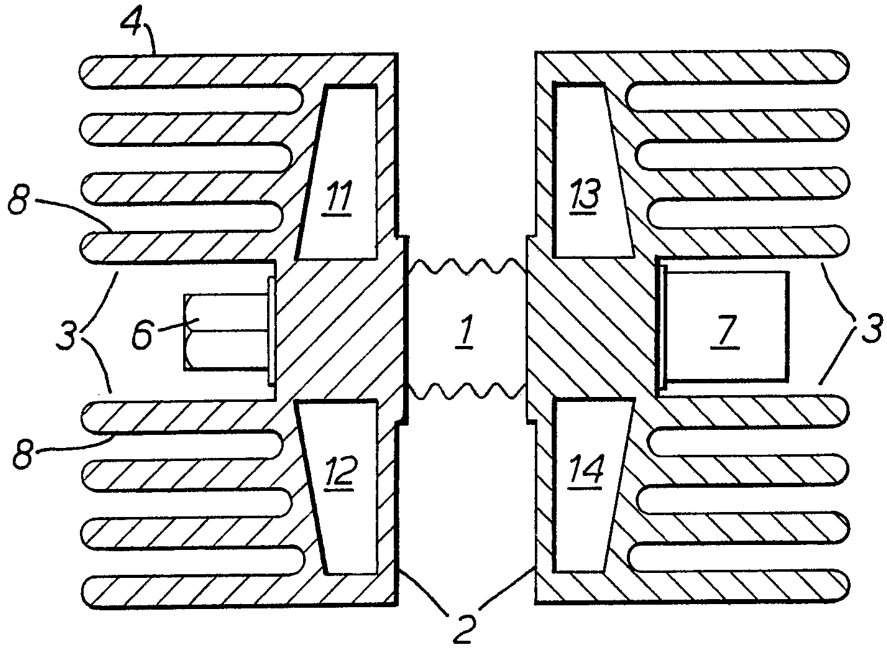

FIG. 1.

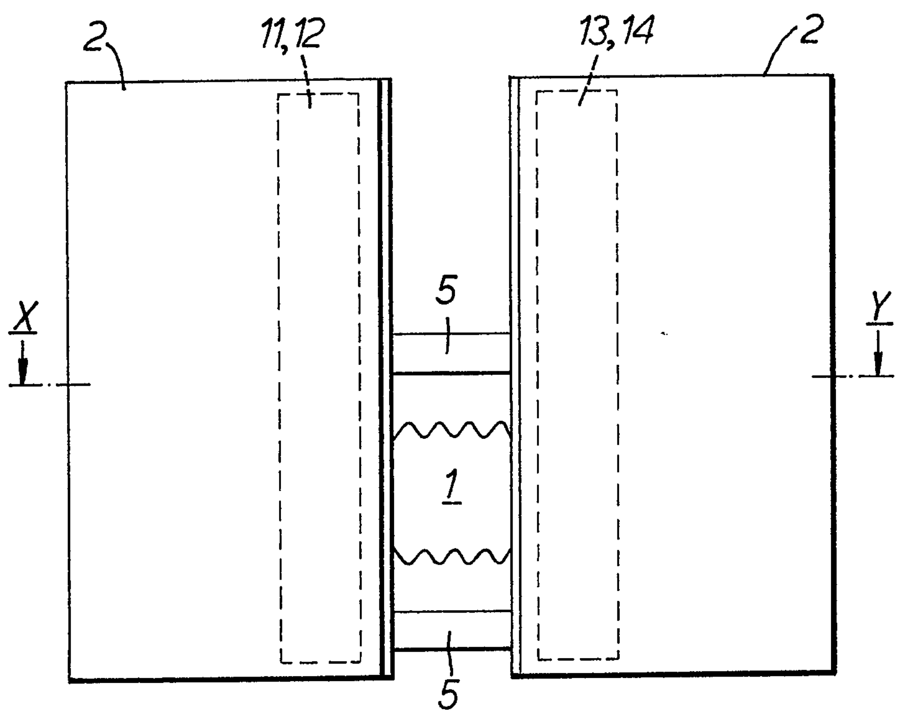

FIG. 2.

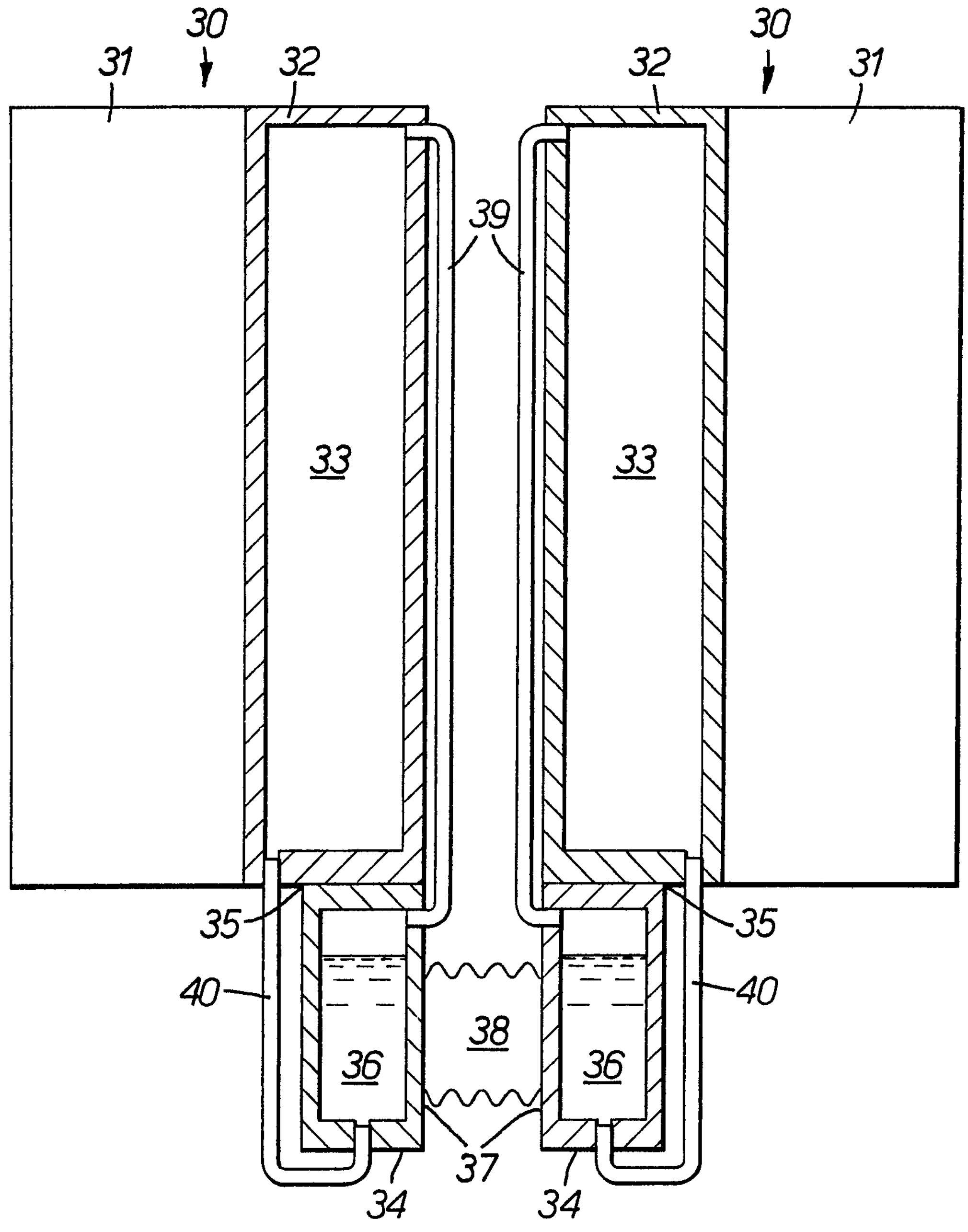

FIG. 3.

SPECIFICATION

Cooling arrangement

This invention relates to a cooling arrangement of the kind which comprises a heat sink formed of a material of good thermal conductivity. Heat sinks are often used to cool high power semiconductor devices, and in such cases the heat sinks commonly are provided with fins which extend the surface area of the heat sink and facilitate dissipation of heat to the surrounding air, or to a fluid coolant which is forced over the fins. The thermal performance of heat sinks can be less than desired; that is to say, they conduct insufficient heat and this is largely because their thermal impedance permits thermal gradients to exist between the relatively localised points at which heat is generated and the regions at which the heat is dissipated.

The present invention seeks to provide an improved cooling arrangement.

According to a first aspect of this invention, a heat sink which is composed of material of good thermal conductivity is provided with a chamber formed within it; the chamber being partially filled with a liquid which is in direct contact with said material, and which liquid vapourises on being heated to constitute a thermosyphon.

According to a second aspect of this invention, a heat sink includes a body of material having a good thermal conductivity and a finned portion of which is shaped to enhance heat dissipation therefrom, a surface region of said body being adapted to receive a heat emitting member; a chamber located within said body and being located generally between said finned portion and said surface region; and a liquid which partially fills the sealed chamber and which readily forms a vapour so that the chamber constitutes an isothermal region within said body.

The temperature difference across the chamber can be held negligibly small, and thus the heat transfer through the chamber is very high indeed, and the heat can be very efficiently transferred to the finned portions where it is dissipated.

In one embodiment of the invention two chambers are formed within a heat sink, a first chamber of which is located adjacent to said surface region and is partially filled with a volatile liquid, and the second chamber of which is adjacent said finned portion and is arranged to receive vapour via a duct from said first chamber and to condense it, said second chamber constituting a substantially isothermal region within the heat sink. The heat sink may consist of a single body, but to ease manufacture, preferably said first chamber is formed in a separate heat sink member which is in close thermal communication with another heat sink member which includes the finned portion and said second chamber.

Preferably the liquid condensate is returned to said one body by a separate duct which feeds into the base of said first chamber. Preferably again the duct which is arranged to pass the vapour to said second chamber is located externally of the body of the heat sink. This enables the effective thermal capacity of the duct to be minimised so that the vapour is not cooled prematurely.

This arrangement enables much more heat to be transferred from a hot body, such as a high power semiconductor device, than is the case with a conventional solid heat sink of similar size and shape. This is a great advantage, as even very small semiconductor devices can operate at very high power levels, but are easily damaged if their temperature is allowed to rise above a predetermined threshold value. Thus the effectiveness of the heat sink on which such a device is mounted determines the power level at which such a heat dissipating device can be safely operated.

The invention is further described by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a sectional plan view of a cooling arrangement, taken on the line XY of Figure 2,

Figure 2 is an elevation view of the arrangement, and

Figure 3 shows a modified cooling arrangement.

Referring to the drawings, an arrangement for cooling a high power semiconductor device 1, such as a thyristor, consists of two large aluminium alloy heat sinks 2 having large fins 3 which enable the external surface of the heat sinks to be maximised. The fins 3 run vertically, and are of constant cross-section along the vertical length of the heat sink 2, which is formed as an extrusion. It is desirable to maximise the external surface area of the heat sinks as this permits more efficient transfer of heat to the surroundings.

The two heat sinks are firmly clamped together by means of two tie bolts 5, each having a head 6 and a pressure indicating assembly 7. The purpose of the pressure indicating assembly is to permit the optimum clamping force to be applied to the device 1, which gives good thermal contact with the heat sinks 2 without applying an excessive damaging pressure to the device 1.

In this example, the fins run vertically, and dissipate heat by radiation and conduction to the air in which cooling arrangement is mounted. The transfer of heat from the heat sink can be improved by the use of forced air cooling, i.e. air is blown at speed over the surfaces of the heat sink. It is not necessary to locate the semiconductor device between two finned heat sinks, as for some purposes a single heat sink may be sufficient, and indeed there may be insufficient space to accommodate both.

It has been found that the transfer of heat through the body of the heat sink from the semiconductor device to the fins 3 is an inefficient process even if the thermal conductivity of the material of the heat sink is very high. Quite large temperatures exist across the heat sink, and in practice, the outer fins 4 in a conventional heat sink, contribute little to the extraction of heat from the device 1, as do the outer tips 8 of the central fins. For this reason, there is very little point in increasing the physical size of the heat sink or the number of vertical fins. The heat from the device 1 must be conducted entirely through the relatively small contact regions.

The present invention enables the effectiveness of the cooling arrangement to be very greatly improved by incorporating thermosyphons 11, 12, 13, 14, directly into the interior of the two heat sinks 2. Each thermosyphon is simply an elongate vertically extending cavity which is sealed and whose walls are constituted by the respective heat sink itself. Each thermosyphon contains an amount of liquid which only partially fills the cavity, and which readily forms a vapour when heated.

As the orientation of the thermosyphon cavities is vertical, in this example, the heated liquid forms a vapour which is condensed by the cooler upper regions of the cavities, and then drains back into the reservoir. The heating and cooling cycle occurs with negligible temperature variations, and thus each thermosyphon cavity acts as a large isothermal region, acting both vertically and horizontally. As the outer walls of the thermosyphons are all at substantially the same temperature, the bases of each fin are also at the same temperature which means that all of the fins are dissipating a similar amount of heat.

Thus the heat sink shown in the drawings is able to dissipate overall much more heat than a conventional heat sink, and avoids the occurrence of local hot spots. An additional great advantage is that the width and height of a finned heat sink can be increased to give a corresponding increase in heat handling capability as even the outermost fins contribute to the heat transfer.

The use of the heat sink 2 itself to define and constitute the boundaries of the thermosyphon gives an extremely good thermal path with the interior of the thermosyphon cavity,as no additional interfaces are required, as would be the case if a separate thermosyphon device were used. In the configuration and orientation shown in the drawings, a simple thermosyphon is quite adequate, but if a different orientation is required, a so-called heat pipe can be used instead. A heat pipe is a thermal syphon in which a wick structure is used to return condensed liquid to a central pool. A suitable liquid for use in a thermosyphon is pentane, and the upper and lower ends of the cavities are sealed by a material which is not attacked by pentane vapour.

Figure 3 shows an alternative configuration which can exhibit certain advantages under some circumstances. The cooling arrangement is somewhat similar to Figure 2, but separate heating and condensing chambers are provided, each of which constitutes an approximately isothermal region. As before, two heat sinks are clamped together to sandwich a semiconductor device between them. Each heat sink consists of an upper portion 30, having fins 31 lying in vertical planes, and a base region 32 which contains two long chambers 33 which extend over the vertical length of the portion 30. In Figure 3, only one chamber 33 in each heat sink portion 30 is visible.

A relatively small heat sink block 34 is mounted on the lower end of each heat sink portion 30. Each block is formed of a similar material to the heat sink portion 30, and is mounted so as to be in excellent thermal contact therewith this is achieved by forming an interface 35 having very flat and smooth surfaces. The blocks 34 each have an internal chamber 36 which is adjacent to an external surface region 37 in contact with the semiconductor device 38. The chambers 36 contain a reservoir of liquid such as pentane or freon which is readily vapourised by heat from the device 38. The vapour rises and is conducted via an external duct 39 to the top of the respective chamber 33, where the vapour is condensed. The condensate drains back to the reservoir in the chamber 36 via a respective duct 40.

The mode of operation is similar to that of Figures 1 and 2, but as the duct 39 which carries the hot vapour is external to the heat sink itself, the duct has a relatively low thermal capacity and does not significantly cool the vapour. Thus the bulk of the vapour is transferred to the top of the chamber 33, which is therefore at substantially the same temperature as the heated liquid in the chamber 36. The duct 40 feeds the condensed liquid back into the base of the chamber 36 so that it does not directly cool the vapour which is produced at the surface of the liquid reservoir.

The chambers 33 each constitute large substantially isothermal regions, and ensure that heat is applied efficiently to the entire length of the basis of the fins, thereby enabling the more remote fins to conduct heat as well as those more closely adjacent to the semiconductor device 38. The riser ducts 39 can be formed integrally with a respective heat sink 30, but care must be taken in their design so that the vapour is not cooled and condensed before it is transferred to the chambers 33.

CLAIMS

1. A heat sink which is composed of material of good thermal conductivity and which is provided with a chamber formed within it; the chamber being partially filled with a liquid which is in direct contact with said material, and which liquid vapourises on being heated to constitute a thermosyphon.

2. A heat sink including a body of material having a good thermal conductivity and a finned portion of which is shaped to enhance heat dissipation therefrom, a surface region of said body being adapted to receive a heat emitting member; a chamber located within said body and being located generally between said finned portion and said surface region; and a liquid which partially fills the sealed chamber and which readily forms a vapour so that the chamber constitutes an isothermal region within said body.

3. A heat sink as claimed in claim 2 and wherein the cavity extends the length of the heat sink and a portion of it is adjacent a heat input surface region of the heat sink.

4. A heat sink as claimed in claim 3 and wherein the heat sink is formed as a longitudinal extrusion, with the cavity being formed during the

extrusion process.

5. A heat sink including a body of material having a good thermal conductivity and a finned portion of which is shaped to enhance heat dissipation therefrom, a surface region of said body adapted to receive a heat emitting member; a first chamber formed within said body adjacent to said surface region and which is partially filled with a volatile liquid; and a second chamber formed within said body adjacent to said finned portion, and which is arranged to receive vapour via a duct from said first chamber and to condense it, said second chamber constituting a substantially isothermal region within the heat sink.

6. A heat sink as claimed in claim 5, and wherein said first chamber is formed in a separate heat sink member which is in close thermal communication with another heat sink member which includes the finned portion and said second chamber.

7. A heat sink as claimed in claim 5 or 6 and wherein the liquid condensate is returned to said one body by a separate duct which feeds into the base of said first chamber.

8. A heat sink as claimed in claim 5, 6 or 7 and wherein the duct which is arranged to pass the vapour to said second chamber is located externally of the body of the heat sink.

9. A heat sink as claimed in any of the preceding claims and wherein said liquid is freon or pentane.

10. A heat sink as claimed in any of the preceding claims and wherein the material of the heat sink is aluminium or an alloy thereof.

11. A heat sink substantially as illustrated in and described with reference to the accompanying drawings.

Amendments to the claims have been filed, and have the following effect:-

(a) Claims 1 to 4 and 8 above have been deleted or textually amended.

(b) New or textually amended claims have been filed as follows:-

4. A heat sink as claimed in claim 1, 2 or 3 and wherein the duct is arranged to pass the vapour to said second chamber is located externally of the body of the heat sink.

(c) Claims 5, 6, 7, 9, 10, 11 above have been renumbered as 1, 2, 3, 5, 6, 7 and their appendancies corrected.

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