HEAT SINK APPARATUS AND METHOD OF MANUFACTURE

This invention relates to heat sink apparatus designed to be used with semiconductor encasement structures and packages to dissipate thermal energy generated by such devices into the surrounding environment and to methods of manufacturing such heat sink apparatus.

Many semiconductor devices generate heat during operation which must be dissipated to avoid damage to the device. Some such devices have power-handling limitations which are largely determined by their ability to lose internally-generated heat and thereby avoid general or localised thermal degradations or failures within them.

In some semiconductor devices, the internally-generated heat is dissipated sufficiently by the enclosure, header or leads of the device. In many semiconductor devices, however, it is necessary to aid the dissipation of internally-generated heat by the use of heat sinks. A wide variety of heat sink designs have been employed for dissipation of internally-generated heat from electronic device packages which house semiconductor devices. For the purpose of the present invention, a heat sink is any body of metal or like material which is placed in contact with an electronic device package for transferring internally-generated heat from the semiconductor device contained in the electronic device package and for rapid dissipation of the internally-generated heat to the atmosphere by conduction, convection and/or radiation.

Generally, heat sinks are constructed of materials, usually metals such as aluminium alloys, cooper and cooper alloys, having high thermal conductivity and are formed into shapes adapted to convect or radiate heat at a high rate. As electronic device packages become more compact and generate more heat, more efficient heat sinks must be devised.

In order for the heat sink to operate efficiently, it must be secured to and placed in good thermal contact with the electronic device package. Various means have been used to attach a heat sink in good thermal contact with an electronic device package. It is known to glue or otherwise adhesively attach a heat sink to a predetermined surface of the electronic device package with heat-conductive epoxy resin or the like which allows removal of heat from the electronic device package. Heat sinks are also mechanically attached to electronic device packages such as by resilient metal clips mounted on the heat sinks which urge the heat sinks and the electronic device packages into mutual contact. The clips enable the heat sinks to be easily removed from the electronic device packages.

It is also desirable to apply various surface treatments to the exterior surfaces of heat sinks. Such surface treatments may include, but are not limited to, anodization, electrodeposition, diffusion coating, galvanisation, cladding, sprayed metal or paint coatings and conversion coatings as well as various forms of enamels, plastics, rubbers and vacuum-deposited coatings. These treatments are beneficial in that they protect the heat sink from corrosion caused

by moisture or other materials in the environment. In addition, certain of the surface treatments described above enable the heat sink to be selectively coloured. Darker colours are desirable in that they enhance the ability of the heat sink to radiate heat to the atmosphere during use.

It is the object of the present invention to provide a method of manufacturing apparatus for removal of heat from a heat generating component which avoids many of the prior art deficiencies, including poor heat transfer efficiency and complicated mounting arrangements.

According to the present invention there is provided a method of manufacturing a unitary heat sink apparatus for use in the removal of heat from a heat generating component, the heat sink comprising a unitary body of heat conducting material having a base surface on a first side thereof adapted to be positioned in thermally conducting contact with the heat generating component and a plurality of parallel first grooves, which define fins extending outwardly on a second side of the body opposite to the first side, the ratio of the height of the fins to the width of the grooves being at least 6 to 1, the method including sawing into the said body of heat conducting material to form the said first grooves.

In one embodiment the body is extruded from heat conducting material, a plurality of grooves being formed in the body by the extrusion such that the ratio of the depth of the grooves to the width of the fins is at least 4 to 1, whereafter the depth of the groove is increased by sawing to form the first grooves.

In a preferred method, the grooves are formed by

gang-sawing the body.

The method may include forming a plurality of second grooves in the body by sawing, which grooves intersect the first grooves such that the fins are discontinuous and comprise parallel rows of pins, the ratio of the height of the pins to the width of the second grooves being at least 6 to 1.

The present invention provides a very simple method of manufacturing a heat sink with an increased heat dissipating surface area for a given area of contact with the heat generating component. When the fins are sawn to define pins forced cooling air may be applied from any side or be directed onto the top of the unitary heat sink apparatus.

The present invention can be put into practice in several ways some of which will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a simplified perspective view of heat sink apparatus at an intermediate stage of fabrication in accordance with the present invention;

Figure 2 is a simplified perspective view of one embodiment of heat sink apparatus according to the present invention; and

Figure 3 is a simplified perspective view of another embodiment of heat sink apparatus according to the present invention.

Heat sinks for semiconductor device packages are usually formed by extrusion processes or by stamping aluminium or aluminium alloys because these processes are highly efficient and cost-effective. As semiconductor device packages become more compact and generate more heat, the need arises for more efficient heat sink apparatus. It will be appreciated that the efficiency of the heat sink apparatus is increased by increasing the surface area of the heat dissipating surfaces of the heat sink apparatus and is even further increased when forced air cooling is used in conjunction with heat dissipating surfaces.

One method to provide an increase in the heat dissipating surface is to provide the heat sink apparatus with fins. It will be appreciated that the fins should have sufficient thickness to be mechanically stable and should be spaced apart at least 0.060 (0.1524cm) to 0.080 inch (0.2032 cm) to allow adequate airflow across or along the surfaces of the fins. It has been determined by the inventor that one means to increase the efficiency of fins on heat sink apparatus is to provide fins which have a ratio of the height of the fins to the spacing dimension between the fins of greater than four to one and in fact of at least six or eight to one. Unfortunately, thin closely-spaced fins cannot be successfully extruded where the fin height to spacing ratio exceeds approximately four to one. Similarly, multi-finned heat sinks with long parallel fins are extremely difficult to manufacture by stamping processes.

FIGURE 1 shows heat sink apparatus 10 in an intermediate phase of manufacture or fabrication thereof which comprises a unitary member constructed from material capable of being extruded and having a high heat transfer coefficient. The heat sink apparatus 10 is preferably constructed from aluminium, aluminium alloys, copper, copper alloys or the like.

The heat sink apparatus 10 as disclosed in FIGURE 1 has been formed by extrusion wherein the fin height to spacing ratio is approximately four to one. The extrusion process is used during this first phase of manufacture in order to conserve material and process time. The heat sink apparatus 10 comprises a base portion 12 with a first number of parallel fins 14 projecting a height p from the upper portion of said base portion 12 and at an angle from said base portion 12. In the preferred embodiments, this angle is approximately ninety degrees.

The base portion 12 includes a base surface 16 which is smooth and flat and, in the preferred embodiments, is rectangular or square in shape. The base surface, however, may be of any shape or dimensions required to mate with the required surface of the device package. The parallel fins 14 are separated by parallel grooves 18 which are of a width f as measured between adjacent parallel fins 14 and are of a width d. As will be appreciated, the depth of the parallel grooves 18 is equal to the height p of the parallel fins 14 from base portion 12. The height of the base portion 12 is measured from the base surface 16 to the bottom surface 20 of the parallel grooves 18. The bottom of surface

20 is in the same plane as the upper portion of the base portion 12.

One method of increasing the efficiency of the heat sink apparatus 10 is to increase the ratio of fin height to spacing dimension between the fins to a value greater than approximately four to one. This increase in efficiency of the heat sink apparatus 10 of FIGURE 1 may be accomplished by increasing the depth of the parallel grooves 18. One method of increasing the depth of the parallel grooves 18 is by sawing with an appropriate saw device which will provide gang sawing of all the parallel grooves 18 simultaneously to the same depth and which will result in a ratio of fin height to groove width of at least six to one and preferably of at least eight to one.

FIGURE 2 shoes heat sink apparatus 10 with a fin height to groove width ratio of at least six to one. A specific embodiment of the heat sink 10 of FIGURE 2 which is to be used with a gate array semiconductor device has a base surface approximately one and one-half inches (3.81 cms) square with parallel fins 14 approximately 0.80 inch (2.032 cms) in height and approximately 0.07 inch (0.1778 cm) wide. It will be appreciated that this ratio of fin height to groove width may be provided for and with a great variety of base surface dimensions for various semiconductor device packages. The base surface 16 will be positioned against the heat transfer surface of the semiconductor device package and held in contact with the same for good thermal transfer between the two surfaces. The preferred method to maintain good

thermal contact between the two surfaces is to glue or otherwise adhesively attach the two surfaces together.

With further reference to FIGURE 2, it will be appreciated that another method may be used to provide heat sink apparatus 10 with the desired ratio of fin height to groove width. This method includes the steps of providing a block or blank form of preferred material and then sawing the required number of grooves of desired width in the material in single saw passes or with ganged saws without first extruding a heat sink with the shorter parallel fins. The saw cuts, of course, must be parallel and separated by the correct distance to provide the desired fin width. It will be appreciated that both methods provide essentially the same heat sink apparatus 20 as shown in FIGURE 2. In both processes of fabrication of the heat sink apparatus 10, the heat sink is anodised or otherwise treated for protection against corrosion and to enhance the heat dissipation characteristics thereof.

To further improve the overall efficiency, the heat sink 10 may be rotated (preferably through ninety degrees) prior to anodising and gang sawed to form a second number of parallel grooves 22 of predetermined width at an angle to the parallel grooves 18, thus providing a dense pin heat sink apparatus 24 as shown in FIGURE 3. This method converts the continuous parallel fins 14 into a plurality of discontinuous fins, each of which comprises a multiplicity of pins 26 extending in a row and thus increases the surface area of the heat dissipating surfaces (previously provided by the parallel fins) for given dimensions of base

surface 16. An additional advantage is that forced cooling air can be applied from any side of the dense pin heat sink apparatus 24 as well as being applied directly down onto the top of the pins 26. It will be observed that when the groove width formed by the sawing in both directions is approximately equal to the fin width, the pin surface area (viewed from the top) is approximately twenty-five percent (25%) of the surface are of the base surface. However, each pin now presents four vertical surfaces to the atmosphere for dissipation of heat. However, when the groove width is less than the fin width, converting the parallel fins to pins increases both the density in number of pins per unit of area and the surface area of pins exposed to the environment. Thus the invention permits the formation or heat sinks with a very high ratio of exposed surface area to base surface area.

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CLAIMS

1. A method of manufacturing a unitary heat sink apparatus for use in the removal of heat from a heat generating component, the heat sink comprising a unitary body of heat conducting material having a base surface on a first side thereof adapted to be positioned in thermally conducting contact with the heat generating component and a plurality of parallel first grooves, which define fins extending outwardly on a second side of the body opposite to the first side, the ratio of the height of the fins to the width of the grooves being at least 6 to 1, the method including sawing into the said body of heat conducting material to form the said first grooves.

2. A method as claimed in claim 1 in which the body is extruded from heat conducting material, a plurality of grooves being formed in the body by the extrusion such that the ratio of the depth of the grooves to the width of the fins is at least 4 to 1, whereafter the depth of the groove is increased by sawing to form the first grooves.

3. A method as claimed in claim 1 or 2 in which the grooves are gang-sawn.

4. A method as claimed in claims 1, 2 or 3 comprising forming a plurality of second grooves in the body by sawing, which grooves intersect the first grooves such that the fins are discontinuous and comprise parallel rows of pins, the ratio of the height of the pins to the width of the second grooves being at least 6 to 1.

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5. A method as claimed in claim 4 comprising sawing the grooves such that each pin is spaced from an adjacent pin by a distance which is less than the width of the pin in the same direction.

6. A method as claimed in claim 4 or claim 5 wherein the first and second grooves are sawn to the same depth.

7. A method as claimed in any preceding claim including coating the external surface of the heat sink apparatus to enhance its thermal transfer coefficient and/or protect it from corrosive attack.

8. A method as claimed in claim 7 including anodising the external surface of the heat sink apparatus.

9. A method as claimed in any preceding claim including sawing the grooves such that the width of each groove is at least 0.06 inch (0.1524 cm).

10. A method of making a unitary heat sink apparatus substantially as specifically described herein with reference to Figures 1 and 2, optionally as modified by Figure 3, of the accompanying drawings.