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TAKIGAWA et al.(10) **Pub. No.: US 2013/0175021 A1**(43) **Pub. Date: Jul. 11, 2013**(54) **SERVO AMPLIFIER WITH HEAT SINK
HAVING TWO SETS OF HEAT-RELEASING
PLATES PERPENDICULAR TO EACH OTHER****Publication Classification**(51) **Int. Cl.**
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(57) **ABSTRACT**

A servo amplifier having a heat sink of low (assembly) cost, with high heat-releasing capacity and reliability, capable of being safely used under high temperature. The heat sink has a base plate, a heat-transferring plate thermally connected to the base plate, a plurality of first heat-releasing fins extending from the base plate, and a plurality of second heat-releasing fins extending from the heat-transferring plate. The first heat-releasing fins are arranged so as to extend from a second major surface of the base plate in the Z-direction, and the second heat-releasing fins are arranged on a region of the both surfaces of the heat-transferring plate where is separated from the second major surface by at least the height of the first heat-releasing fins, the second heat-releasing fins extending generally parallel to second major surface.

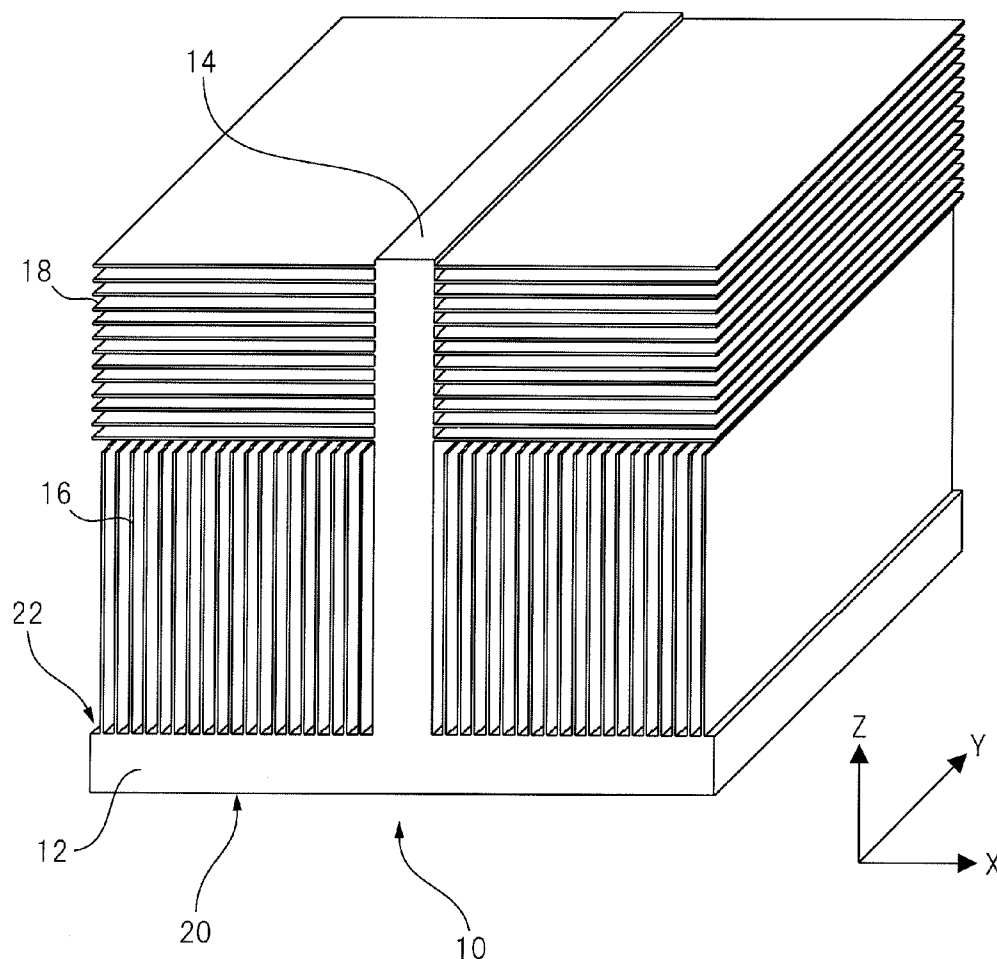


FIG. 1

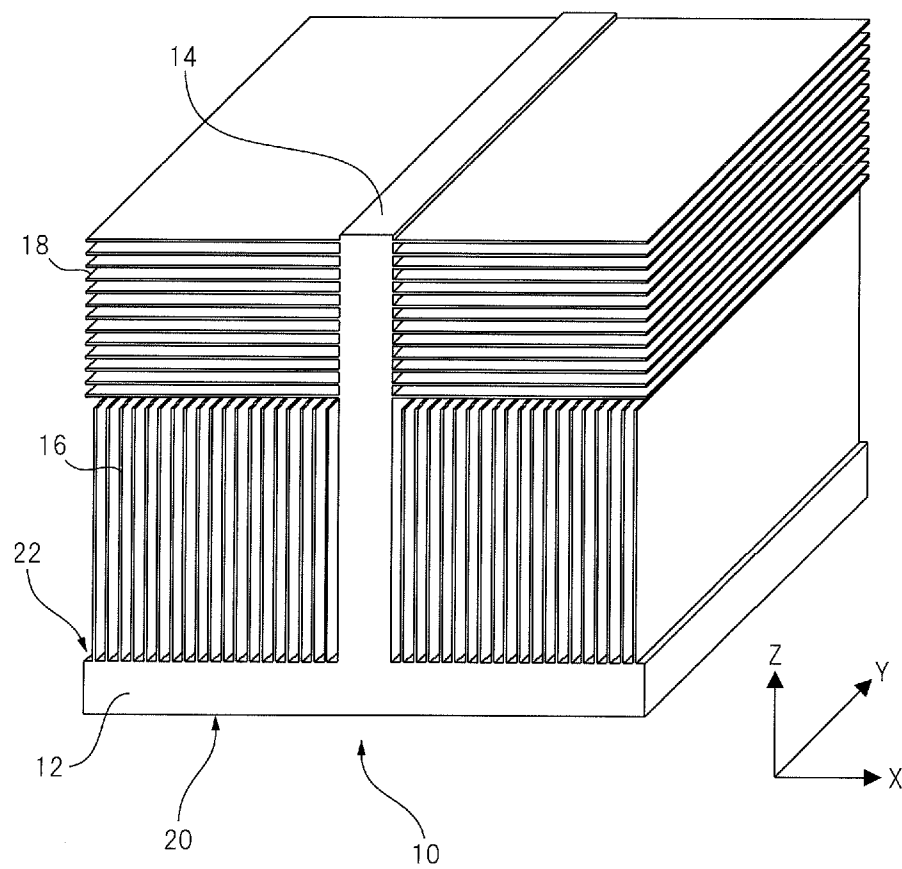


FIG. 2

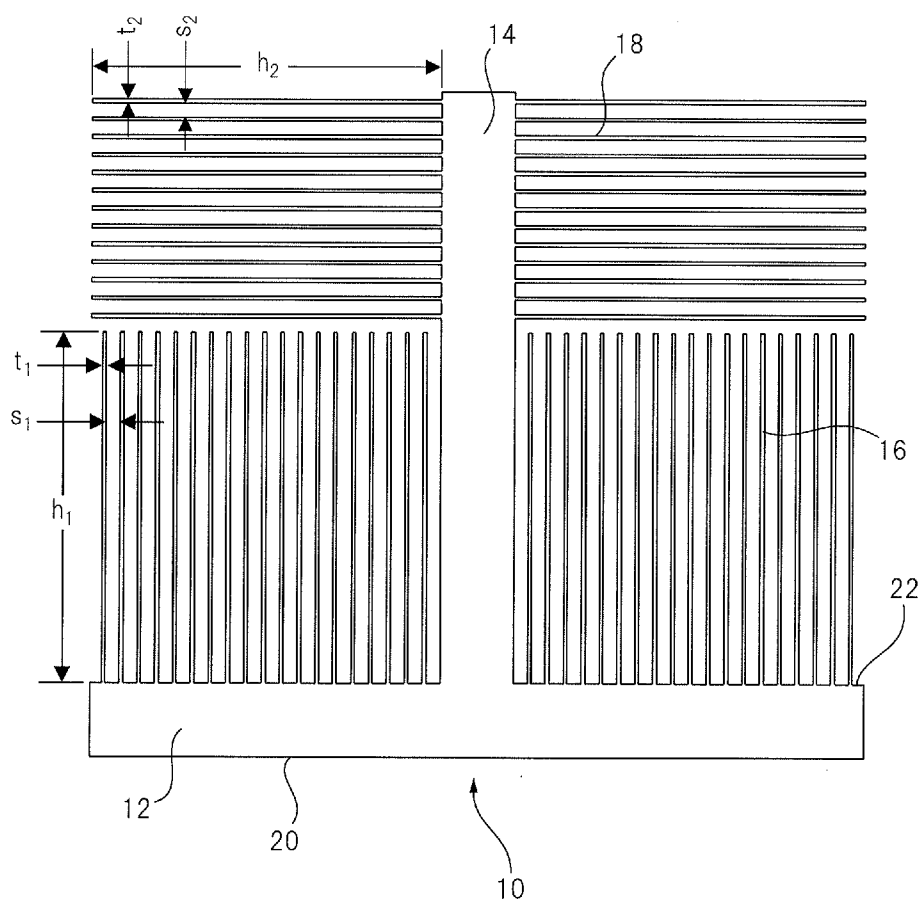


FIG.3

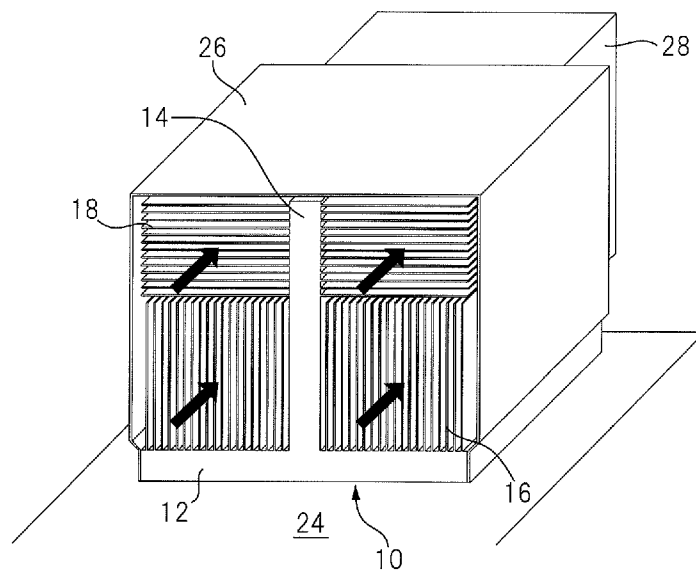


FIG.4

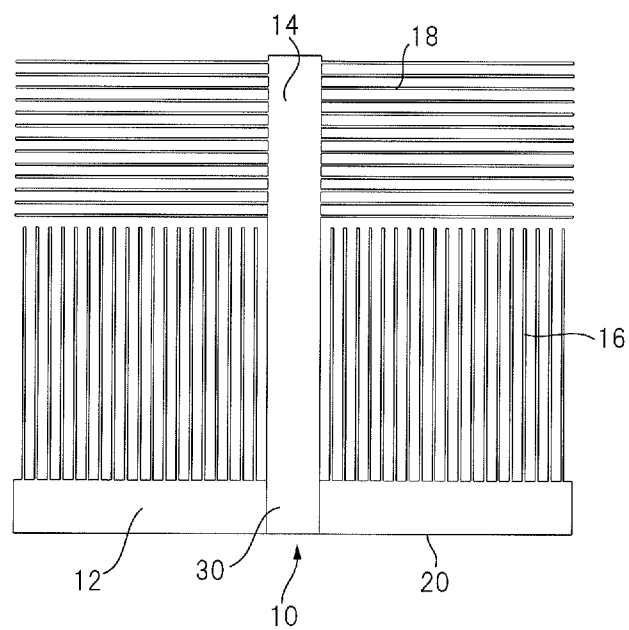


FIG.5

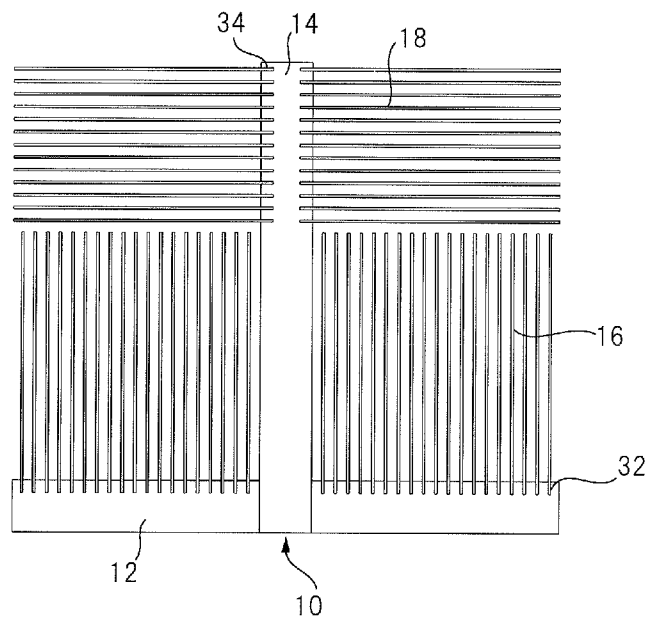


FIG.6

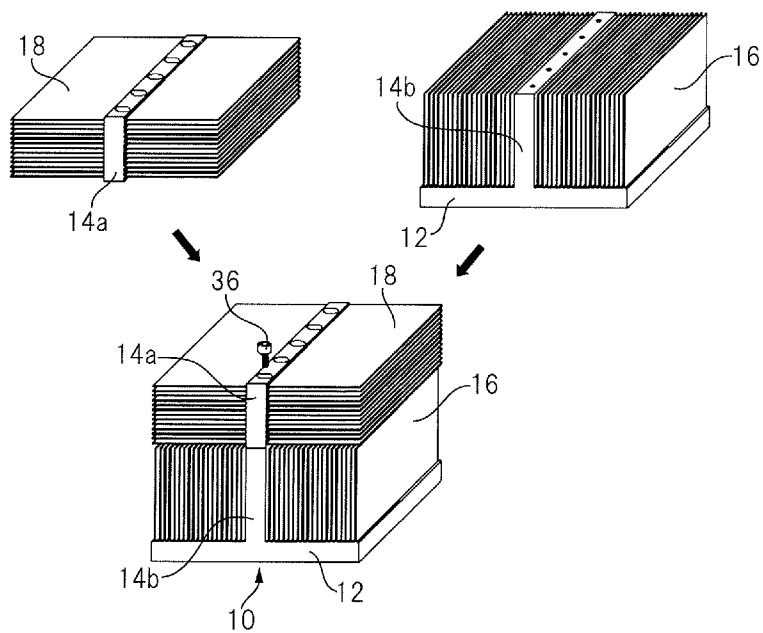
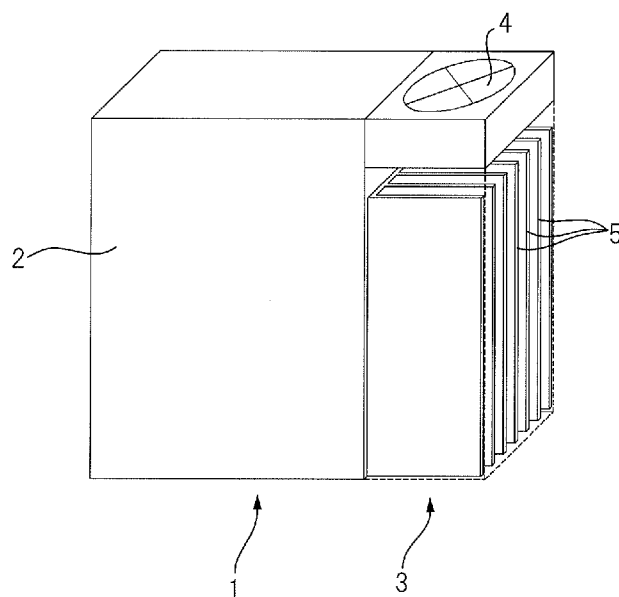


FIG. 7

PRIOR ART



SERVO AMPLIFIER WITH HEAT SINK HAVING TWO SETS OF HEAT-RELEASING PLATES PERPENDICULAR TO EACH OTHER

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to a servo amplifier with a heat sink for releasing heat generated from components such as a power semiconductor device, etc.

[0003] 2. Description of the Related Art

[0004] Generally, in a servo amplifier, an amount of heat generation from a power semiconductor device, etc., is increased due to an increase in output thereof. Therefore, in a high-powered servo amplifier, a heat sink for releasing the generated heat outside is attached to the servo amplifier, and a surface area of the heat sink is increased for improving heat releasing efficiency.

[0005] For example, in a servo amplifier **1** schematically shown in FIG. 7, a heat sink **3** having a relatively large volume is attached to a servo amplifier body **2**, and a fan **4** is used to increase heat releasing capacity from heat sink **3**. Further, in order to obtain a large heat releasing surface area within the limited volume, generally, a plurality of thin fins **5** are positioned at a narrow pitch so as to increase the number of the fins, and the height of each fin **5** (the horizontal length in FIG. 7) is increased. However, in the conventional heat sink as shown in FIG. 7, when each fin **5** is thinner and higher, it is difficult to sufficiently transfer heat to the front end of each fin **5**, i.e., fin efficiency is reduced. Therefore, the effect in increasing the surface area of the fins cannot be sufficiently obtained.

[0006] In order to avoid reducing the fin efficiency, for example, Japanese Unexamined Patent Publication (Kokai) No. 3-96258 discloses a heat-pipe-type cooling device including a heat pipe having an evaporating portion attached to a back side of a base plate and a condensing portion formed by bending the base plate, and a plurality of fins intersecting the condensing portion of the heat pipe.

[0007] Further, Japanese Unexamined Patent Publication (Kokai) No. 2001-196511 discloses a heat sink wherein a heat transfer portion is constituted as a column structure so as to improve thermal diffusion efficiency from a heating element, and pin-shaped fins are positioned at a lateral side of the column so as to obtain a heat releasing area.

[0008] The heat sink, as described in Japanese Unexamined Patent Publication (Kokai) No. 3-96258, may have high heat-releasing performance (or cooling capacity), however, assembly cost thereof is high. Further, when the heat sink is used under high temperature for a long time, performance of a heat pipe may be lowered due to incompressible gas introduced into the heat pipe. In the heat sink having the heat pipe, when the heat pipe is thermally connected to the center or near of a base plate only, heat is not effectively released from the periphery of the base plate.

[0009] On the other hand, the heat sink of Japanese Unexamined Patent Publication (Kokai) No. 2001-196511 is referred to as a tower heat sink, and the temperature at a portion of the heating element which contacts column **2** may be effectively lowered. However, an area of the portion contacting the heating element is considerably small in comparison to the size of the heat sink. Therefore, when the size of the heating element is large, the heat sink merely contacts a portion of the heating element, whereby the temperature at

the periphery of the heating element cannot be sufficiently lowered. Otherwise, it is necessary to use a heat sink larger than the heating element.

[0010] Accordingly, a servo amplifier having a heat sink is desired, wherein the heat sink may be used on a large heating element to which the conventional tower heat sink cannot be applied, without using a heat pipe which has high assembling cost and is inappropriate under high temperature, the heat sink having heat releasing capacity as well as or better than a heat sink having a heat pipe.

SUMMARY OF THE INVENTION

[0011] The object of the present invention is to provide a servo amplifier having a heat sink of low (assembly) cost, with high heat-releasing capacity and reliability, capable of being safely used under high temperature and maintaining a large and high-heat-generating semiconductor device such as a power semiconductor device at a low temperature.

[0012] The present invention provides a servo amplifier having a heat sink for releasing heat, the heat sink comprises: a base plate having a first major surface which functions as a heat-receiving surface which is thermally in contact with a heat generating body, and a second major surface opposed to the first major surface; a heat-transferring plate arranged on a line passing through a generally center of the second major surface of the base plate, from one end to the other end of the second major surface, the heat-transferring plate extending perpendicular to the second major surface; a plurality of first heat-releasing fins positioned at intervals of a first fin pitch, the first heat-releasing fins being arranged on a region of the second major surface except an a region where the heat-transferring plate is arranged, the first heat-releasing fins extending parallel to the heat-transferring plate and perpendicular to the second major surface, a height of each first heat-releasing fin being smaller than the heat-transferring plate; and a plurality of second heat-releasing fins positioned at intervals of a second fin pitch, the second heat-releasing fins being arranged on each surface of the heat-transferring plate where is higher than top edges of the first heat-releasing fins, the second heat-releasing fins extending parallel to the second major surface and perpendicular to each surface of the heat-transferring plate, the second heat-releasing fins extending to generally the same position as a peripheral edge of the second major surface in relation to the extending direction of the second heat-releasing fins.

[0013] In a preferred embodiment, a material, thickness and height of each first heat-releasing fin are the same as a material, thickness and height of each second heat-releasing fin, and the first fin pitch is the same as the second fin pitch.

[0014] In a preferred embodiment, the heat-transferring plate is a copper plate or a copper alloy plate, and at least a portion of the heat-transferring plate extends through the base plate and is exposed to the heat-receiving surface.

[0015] In a preferred embodiment, at least a portion of the first heat-releasing fins and at least a portion of the second heat-releasing fins are fitted with a groove formed on at least one of the base plate and the heat-transferring plate, and fixed to the groove by swaging, soldering, brazing or welding.

[0016] In a preferred embodiment, the heat-transferring plate is constituted by an upper section and a lower section which may be divided at a level generally the same as a height of the top edges of the first heat-releasing fins, and wherein the second heat-releasing fins are arranged on the upper sec-

tion and the first heat-releasing fins are arranged on the base plate connected to the lower section.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The above and other objects, features and advantages of the present invention will be made more apparent by the following description of the preferred embodiments thereof, with reference to the accompanying drawings, wherein:

[0018] FIG. 1 is a perspective view showing a configuration of a heat sink according to a first embodiment of the invention;

[0019] FIG. 2 is a schematic cross-sectional view of the heat sink of FIG. 1;

[0020] FIG. 3 is a perspective view showing a state wherein the heat sink of FIG. 1 is arranged in a duct to which a fan is connected;

[0021] FIG. 4 is a schematic cross-sectional view showing a heat sink according to a second embodiment of the invention;

[0022] FIG. 5 is a schematic cross-sectional view showing a heat sink according to a third embodiment of the invention;

[0023] FIG. 6 is a schematic assembly view showing a perspective of a heat sink according to a fourth embodiment of the invention; and

[0024] FIG. 7 is an example wherein a conventional heat sink is attached to a servo amplifier.

DETAILED DESCRIPTION

[0025] FIG. 1 is a perspective view showing a basic configuration of a heat sink 10 for a servo amplifier, and FIG. 2 is a schematic cross-sectional view of heat sink 10 along a plane parallel to X-Z plane of FIG. 1. Heat sink 10 has a base plate 12, a heat-transferring plate 14 thermally connected to base plate 12, a plurality of first heat-releasing fins 16 extending from base plate 12, and a plurality of second heat-releasing fins 18 extending from heat-transferring plate 14. In the embodiment of FIG. 1, these components are generally rectangular plates made from heat-conductive material. In particular, base plate 12 has a first major surface 20 which functions as a heat-receiving surface which is thermally in contact with a heat generating body such as a body of the servo amplifier, and a second major surface 22 opposed to first major surface 20. In the illustrated embodiment, both of the major surfaces extend parallel to X-Y plane. Heat-transferring plate 14 is arranged on a line passing through a generally center (for example, a gravity center) of second major surface 22, from one end to the other end of second major surface 22, and heat-transferring plate 14 extends in a direction perpendicular to second major surface 22 (in FIG. 1, in the Z-direction).

[0026] As shown in FIG. 2, first heat-releasing fins 16 are aligned in a direction generally perpendicular to a surface of heat-transferring plate 14 (in the X-direction in FIG. 1) at intervals of a predetermined first fin pitch s_1 , the first heat-releasing fins being arranged on a generally entire region of second major surface 22 except for a region where heat-transferring plate 14 is connected, each first heat-releasing fin 16 extending generally parallel to the extending direction (Z-direction) of heat-transferring plate 14 and generally perpendicular to second major surface 22. In the embodiment, each first heat-releasing fin 16 has a thickness t_1 and a height

(or a length in the Z-direction) h_1 . Height h_1 of each first heat-releasing fin 16 is smaller than the height of heat-transferring plate 14.

[0027] On the other hand, second heat-releasing fins 18 are aligned in the extending direction of heat-transferring plate 14 (in the Z-direction in FIG. 1) at intervals of a predetermined second fin pitch s_2 , the second heat-releasing fins being arranged on a region of the both surfaces of heat-transferring plate 14 where is away from second major surface 22 of base plate 12 in the Z-direction by at least height h_1 of first heat-releasing fins 16, second heat-releasing fins 18 extending generally parallel to second major surface 22 (in the X-direction on FIG. 1). In the embodiment, each second heat-releasing fin 18 has a thickness t_2 and a height (or a length in the X-direction) h_2 . Height h_2 of each second heat-releasing fin 18 determined such that second heat-releasing fins 18 extend near a peripheral edge of second major surface 22 (in other words, second heat-releasing fins 18 extend to generally the same X-position as the peripheral edge of base plate 12 extending in the Y-direction).

[0028] FIG. 3 is a perspective view showing a state wherein heat sink 10 of FIG. 1 is applied to a schematically shown servo amplifier 24. Servo amplifier 24 has a power semiconductor device (not shown), and heat sink 10 is used to release heat generated from the power semiconductor device. Heat sink 10 is covered by a cylindrical (or hollow rectangular) casing 26 having opened ends, so as to constitute a duct structure, such that air can flow (in the Y-direction in the embodiment) between each first heat-releasing fin 16 and between each second heat-releasing fin 18. At or near one opened end of casing 26, a cooling fan 28 is arranged. By activating cooling fan 28, an air flow along an arrow as shown in FIG. 3 is generated, and the air flow provides heat removal from the surface of the heat-releasing fins, whereby the temperature of the heat-releasing fins is lowered. By virtue of this, heat of servo amplifier (or the heat generating body) is transferred to the heat-releasing fins via base plate 12 and heat-transferring plate 14.

[0029] Generally, when the height of the heat-releasing fins is increased, thermal resistance from a proximal end to a front end of each heat-releasing fin is increased, it gets harder to transfer heat to the front end of the heat-releasing fin. Therefore, even when a surface area of the fin is increased by increasing the height of the fin, an amount of released heat is not considerably increased (i.e., fin efficiency is lowered). On the other hand, in the first embodiment, the height of first heat-releasing fins 16 is relatively low (concretely, lower than heat-transferring plate 14), a high fin efficiency may be obtained. However, since the amount of released heat from the fin is proportional to a product of the surface area of the fin and the fin efficiency, the amount of released heat is decreased by the first heat-releasing fins only.

[0030] In view of the above, in the present invention, heat-transferring plate 14 having the height higher than first heat-releasing fins 16 is arranged on a line of base plate 12 extending from one end to the other end of base plate 12 through the generally center of base plate 12 such that heat-transferring plate 14 extends from base plate 12 perpendicular to the base plate and parallel to first heat-releasing fins 16. Further, second heat-releasing fins 18 are arranged on the region of the both surfaces of heat-transferring plate 14 where is higher than the top edges of first heat-releasing fins 16 such that second heat-releasing fins 18 extends generally parallel to base plate 12 and near the peripheral edge of base plate 12.

Since second heat-releasing fins **18** are connected to heat-transferring plate **14** having high thermal conductivity and the height of second heat-releasing fins **18** may be equal to or more than the height of first heat-releasing fins **16**, high fin efficiency may be obtained. By virtue of this, although the total surface area of the heat sink (i.e., the total surface areas of the first and second heat-releasing fins) is not substantially changed relative to the prior art, the heat-releasing efficiency of the fins of the heat sink of the invention may be improved.

[0031] Since first heat-releasing fins **16** are arranged on the generally whole region on second major surface **22** of base plate **12** except for a region where heat-transferring plate **14** is arranged, heat may be sufficiently released from the peripheral portion of base plate **12**. Therefore, even when a large heat generating body is attached to the heat receiving surface of the heat sink, it is not likely that the temperature of the peripheral portion of the heat generating body is higher than the temperature of the other portion. Further, in relation to a generally central portion of the large heat generating body, the temperature of which is usually increased, heat is released by second heat-releasing fins **18** via heat-transferring plate **14**, whereby the temperature thereof is prevented from being increased. As a result, the temperature of a portion of the large heat generating body is excessively increased, which may be avoided. In addition, when heat-transferring plate **14** is made from a solid metallic plate, the heat-transferring plate may be manufactured at low cost and performance loss thereof may be avoided, whereby a reliable heat sink having high performance may be realized at low cost.

[0032] In FIG. 2, it is preferable that a material of first heat-releasing fins **16** and a material of second heat-releasing fins **18** are the same, fin thickness t_1 of each first heat releasing fin **16** and fin thickness t_2 of each second heat releasing fin **18** are the same, fin height h_1 of each first heat releasing fin **16** and fin height h_2 of each second heat releasing fin **18** are the same, and first fin pitch s_1 and second fin pitch s_2 are the same. When the material, the thickness and the height of the first and second heat-releasing fins are the same, a heat-transferring condition in each heat-releasing fin may be generally uniform, whereby heat may be effectively released. Generally, when a flow velocity of cooling air is not uniform, heat cannot be effectively released from some heat-releasing fins, whereby the total heat-releasing efficiency may be lowered. However, when the fin pitches are equal to each other, the flow velocity of the cooling air which flows between the fins may be uniform, whereby the heat-releasing efficiency of each fin may be generally constant.

[0033] FIG. 4 shows a second embodiment of a heat sink for a servo amplifier according to the present invention. In the second embodiment, heat-transferring plate **14** is a copper plate or a copper alloy plate, and at least a portion (a lower end **30** in the illustrated embodiment) of the heat-transferring plate extends through base plate **12** and is exposed at the heat receiving surface (or first major surface **20**). By manufacturing heat-transferring plate **14** of copper or a copper alloy having high heat conductivity, thermal resistance between second heat-releasing fins **18** and the heat-receiving surface is lowered, heat is more effectively released from second heat-releasing fins **18** and the heat-releasing performance of the heat sink is improved, while minimizing the weight and the cost of the heat sink. Further, since heat-transferring plate **14** extends through base plate **12** and is exposed at the heat-receiving surface, heat from the heat generating body such as the servo amplifier is directly transferred to heat-transferring

plate **14**, whereby heat is released more effectively. On the other hand, as a material of base plate **12**, aluminum or an aluminum alloy may be used to save on the weight of the heat sink, however, copper or copper alloy may be used similarly as heat-transferring plate **14**.

[0034] FIG. 5 shows a third embodiment of a heat sink for a servo amplifier according to the present invention. In the third embodiment, at least a portion of first heat-releasing fins **16** and at least a portion of second heat-releasing fins **18** are fitted with a groove formed on at least one of base plate **12** and heat-transferring plate **14**, and fixed to the groove by swaging, soldering, brazing or welding. In the illustrated embodiment, first heat-releasing fins **16** are fitted with grooves **32** formed on base plate **12**, and second heat-releasing fins **18** are fitted with grooves **34** formed on heat-transferring plate **14**. In the third embodiment, in comparison to a case wherein the heat-releasing fins are integrally formed with the base plate or the heat-transferring plate by extrusion using a mold, fins having a high tongue ratio (=fin height/space between fins) may be easily manufactured, which is difficult to be manufactured by the extrusion using the mold, whereby the high heat-releasing capacity in the third embodiment. Further, in the third embodiment, in comparison to a case wherein the heat-releasing fins are integrally formed with the base plate and the heat-transferring plate by machining or cutting, the manufacturing cost may be lowered. In addition, in the third embodiment, the heat-releasing fins, the base plate and the heat-transferring plate may be manufactured from the different materials, optimum materials may be respectively selected for these components, whereby the heat-releasing capacity of the heat sink may be improved, and the weight and the cost of the heat sink may be reduced.

[0035] In the first, second and third embodiment, the heat-transferring plate is described as merely a metallic plate. However, in order to obtain higher heat-transferring capacity, a heat pipe or a carbon fiber having high thermal conductivity (not shown) may be embedded in the heat-transferring plate.

[0036] Further, in the first, second and third embodiment, heat-transferring plate **14** is described as substantially a single plate. However, in order to overcome the difficulty in forming or fixing the two sets of heat-releasing fins perpendicular to each other, heat sink **10** may be divided in to two sections as shown in FIG. 6. Concretely, heat-transferring plate **14** is constituted by an upper section **14a** and a lower section **14b** which may be divided at a level generally same as a height of the top edges of first heat-releasing fins **16** (or a level between the height of the top edge and the height of the lowest second heat-releasing fin **18**), second heat-releasing fins **18** are arranged on upper section **14a** similarly to the other embodiment, and first heat-releasing fins **16** are arranged on base plate **12** connected to lower section **14b**, similarly to the other embodiment. As such, the heat-releasing fins may be separately formed or fixed while the heat sink is divided into the upper and lower sections, and then, upper section **14a** and lower section **14b** of the heat-transferring plate may be connected to each other by means of a fastening member such as a screw **36**, etc.

[0037] In the present invention, since the height of the first heat-releasing fins is lower than the heat-transferring plate, the deterioration of the fin efficiency (=the substantial surface area of the fins/the geometric surface area of the fins) due to the difficulty in transferring heat to the front end of each fin is avoided, while the second heat-releasing fins extending from the heat-transferring plate may be arranged in a space where

is away from the base plate and the first heat-releasing fins do not exist. As a result, while limiting the height of the heat-releasing fins, the fin efficiency of each of the first and second heat-releasing fins may be kept high without reducing the total surface area of all of the heat-releasing fins, whereby the heat-releasing capacity of the heat sink may be improved. In particular, the temperature of or near the peripheral portion of the base plate is lowered by the first fins, and the temperature of or near the center portion of the base plate is lowered by the second fins. Therefore, even when a heat spreader, etc., which functions in the same operating principle as the heat pipe, is not used, a large heat generating body such as a power semiconductor device used for a servo amplifier can be uniformly cooled.

[0038] When the material, the fin thickness and the fin height is the same between the first and second heat-releasing fins, the heat-transferring condition in each heat-releasing fin is generally uniform. Further, when the fin pitch is the same between the first and second heat-releasing fins, the flow velocity of the cooling air which flows between each fin by means of the fan is likely to be uniform, the fin efficiency of each heat-releasing fin may be generally uniform within the heat sink, whereby heat can be more effectively released from the heat sink.

[0039] When the heat-transferring plate is a copper or copper alloy plate and a portion of the heat-transferring plate extends through the base plate and is exposed at the heat-receiving surface, while minimizing the weight and the cost of the heat sink, thermal resistance between the second heat-releasing fins and the heat-receiving surface is lowered, whereby heat is more effectively released from the second heat-releasing fins. In particular, when the heat-transferring plate extends through the base plate and is exposed at the heat-receiving surface, heat from the heat generating body is directly transferred to the heat-transferring plate, whereby heat is released more effectively.

[0040] When at least a portion of the first heat-releasing fins and at least a portion of the second heat-releasing fins are fitted with the groove formed on at least one of the base plate and the heat-transferring plate, and fixed to the groove by swaging, soldering, brazing or welding, the high tongue ratio (=fin height/space between fins) may be easily manufactured, which is difficult to be manufactured by extrusion molding, whereby the heat-releasing capacity may be increased and the manufacturing cost may be reduced, in comparison to a case wherein the heat-releasing fins are integrally formed with the base plate and the heat-transferring plate by machining or cutting. Further, optimum materials may be respectively selected for the heat-releasing fins, the base plate and the heat-transferring plate, whereby the heat-releasing capacity of the heat sink may be improved, and the weight and the cost of the heat sink may be reduced.

[0041] When the heat-transferring plate is configured to be divided into upper and lower sections at a level generally same as the height of the top edges of the first heat-releasing fins, the heat sink may be more easily manufactured.

[0042] While the invention has been described with reference to specific embodiments chosen for the purpose of illustration, it should be apparent that numerous modifications

could be made thereto, by a person skilled in the art, without departing from the basic concept and scope of the invention.

1. A servo amplifier having a heat sink for releasing heat, the heat sink comprises:

a base plate having a first major surface which functions as a heat-receiving surface which is thermally in contact with a heat generating body, and a second major surface opposed to the first major surface;

a heat-transferring plate arranged on a line passing through a generally center of the second major surface of the base plate, from one end to the other end of the second major surface, the heat-transferring plate extending perpendicular to the second major surface;

a plurality of first heat-releasing fins positioned at intervals of a first fin pitch, the first heat-releasing fins being arranged on a region of the second major surface except for a region where the heat-transferring plate is arranged, the first heat-releasing fins extending parallel to the heat-transferring plate and perpendicular to the second major surface, a height of each first heat-releasing fin being smaller than the heat-transferring plate; and

a plurality of second heat-releasing fins positioned at intervals of a second fin pitch, the second heat-releasing fins being arranged on each surface of the heat-transferring plate where is higher than top edges of the first heat-releasing fins, the second heat-releasing fins extending parallel to the second major surface and perpendicular to each surface of the heat-transferring plate, the second heat-releasing fins extending to generally the same position as a peripheral edge of the second major surface in relation to the extending direction of the second heat-releasing fins.

2. The servo amplifier as set forth in claim 1, wherein a material, thickness and height of each first heat-releasing fin are the same as a material, thickness and height of each second heat-releasing fin, and the first fin pitch is the same as the second fin pitch.

3. The servo amplifier as set forth in claim 1, wherein the heat-transferring plate is a copper plate or a copper alloy plate, and at least a portion of the heat-transferring plate extends through the base plate and is exposed to the heat-receiving surface.

4. The servo amplifier as set forth in claim 1, wherein at least a portion of the first heat-releasing fins and at least a portion of the second heat-releasing fins are fitted with a groove formed on at least one of the base plate and the heat-transferring plate, and fixed to the groove by swaging, soldering, brazing or welding.

5. The servo amplifier as set forth in claim 1, wherein the heat-transferring plate is constituted by an upper section and a lower section which may be divided at a level generally same as a height of the top edges of the first heat-releasing fins, and wherein the second heat-releasing fins are arranged on the upper section and the first heat-releasing fins are arranged on the base plate connected to the lower section.

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