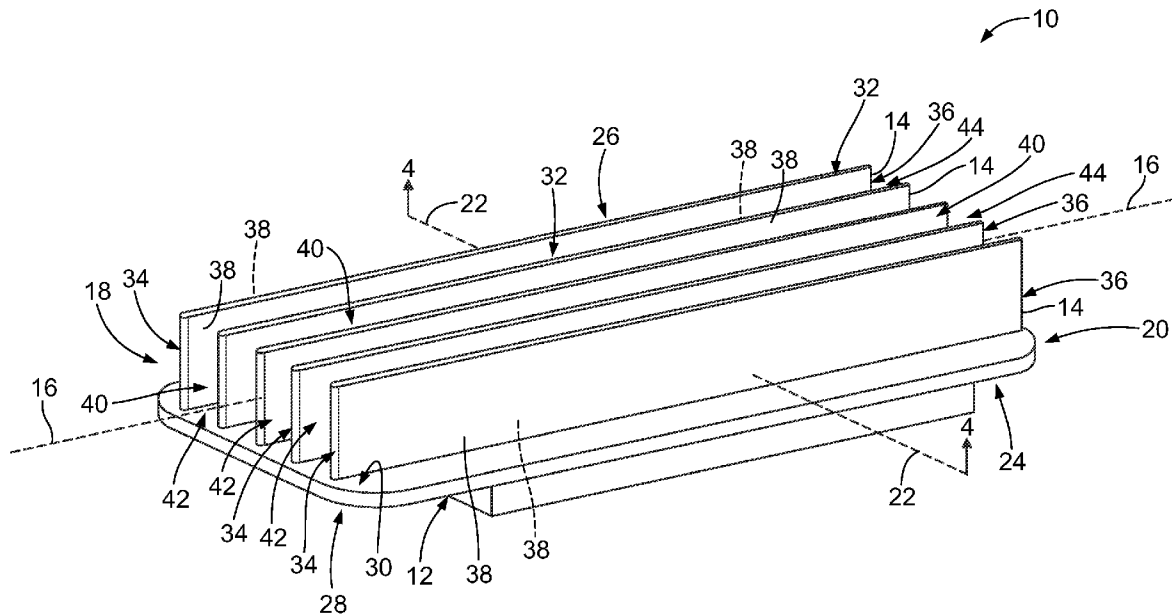




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(19) **United States**(12) **Patent Application Publication**
Nichols(10) **Pub. No.: US 2014/0151010 A1**(43) **Pub. Date: Jun. 5, 2014**(54) **HEAT SINK**(71) Applicant: **TYCO ELECTRONICS CORPORATION**, Berwyn, PA (US)(72) Inventor: **Robert Paul Nichols**, Vacaville, CA (US)(73) Assignee: **Tyco Electronics Corporation**, Berwyn, PA (US)(21) Appl. No.: **13/692,648**(22) Filed: **Dec. 3, 2012****Publication Classification**(51) **Int. Cl.**
F28F 3/02 (2006.01)(52) **U.S. Cl.**CPC **F28F 3/02** (2013.01)USPC **165/185**(57) **ABSTRACT**

A heat sink includes a base having a structure side and an opposite environmental side. The structure side of the base is configured to thermally communicate with a structure for absorbing heat from the structure. A cooling fin extends a height outwardly from the environmental side of the base. The cooling fin extends a cord length along the base from a leading edge to a trailing edge of the cooling fin. The cooling fin includes the cross-sectional shape of an airfoil along at least a portion of the height of the cooling fin to increase the velocity of a flow of air along the cord length of the cooling fin.



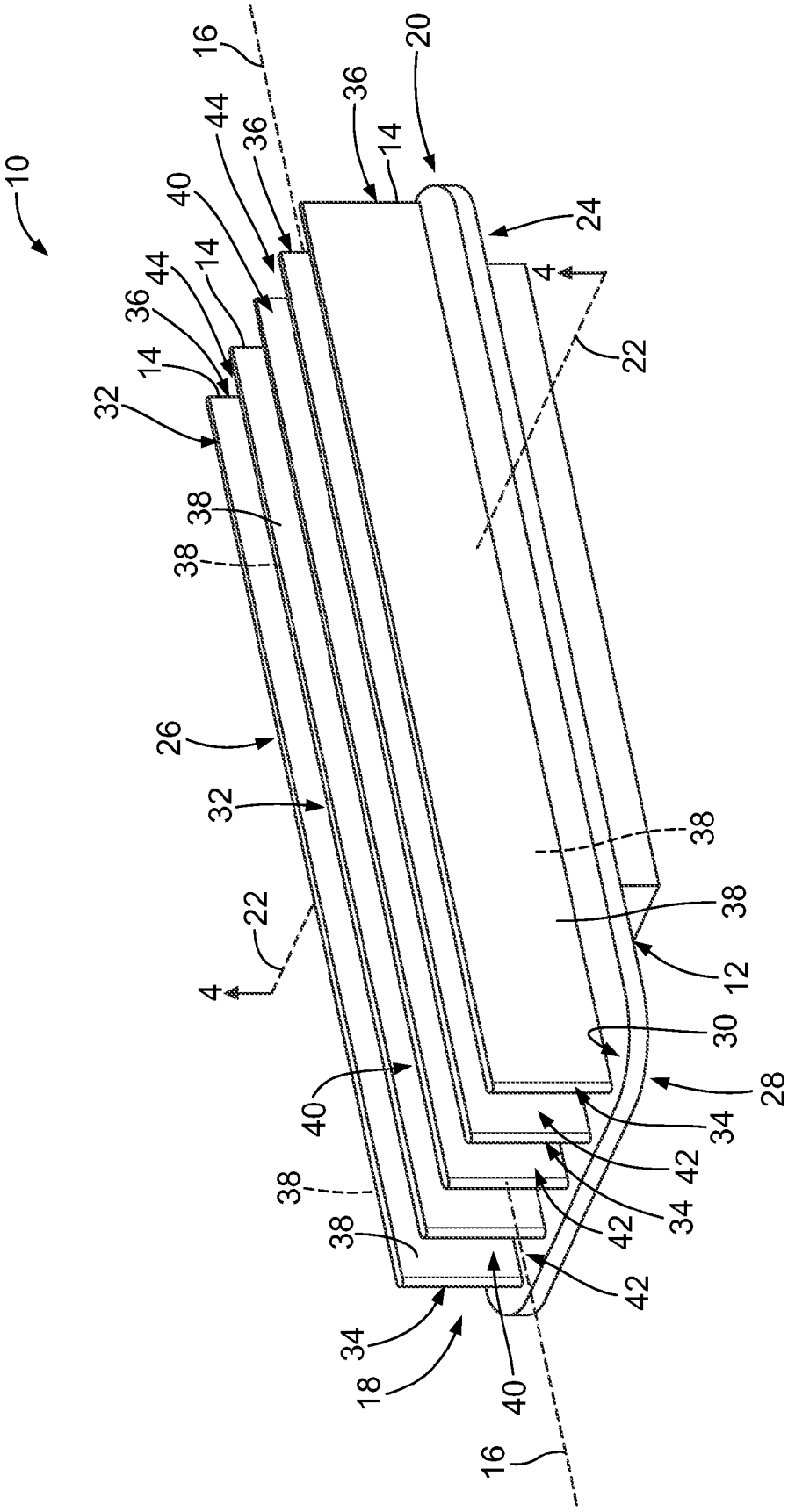


FIG. 1

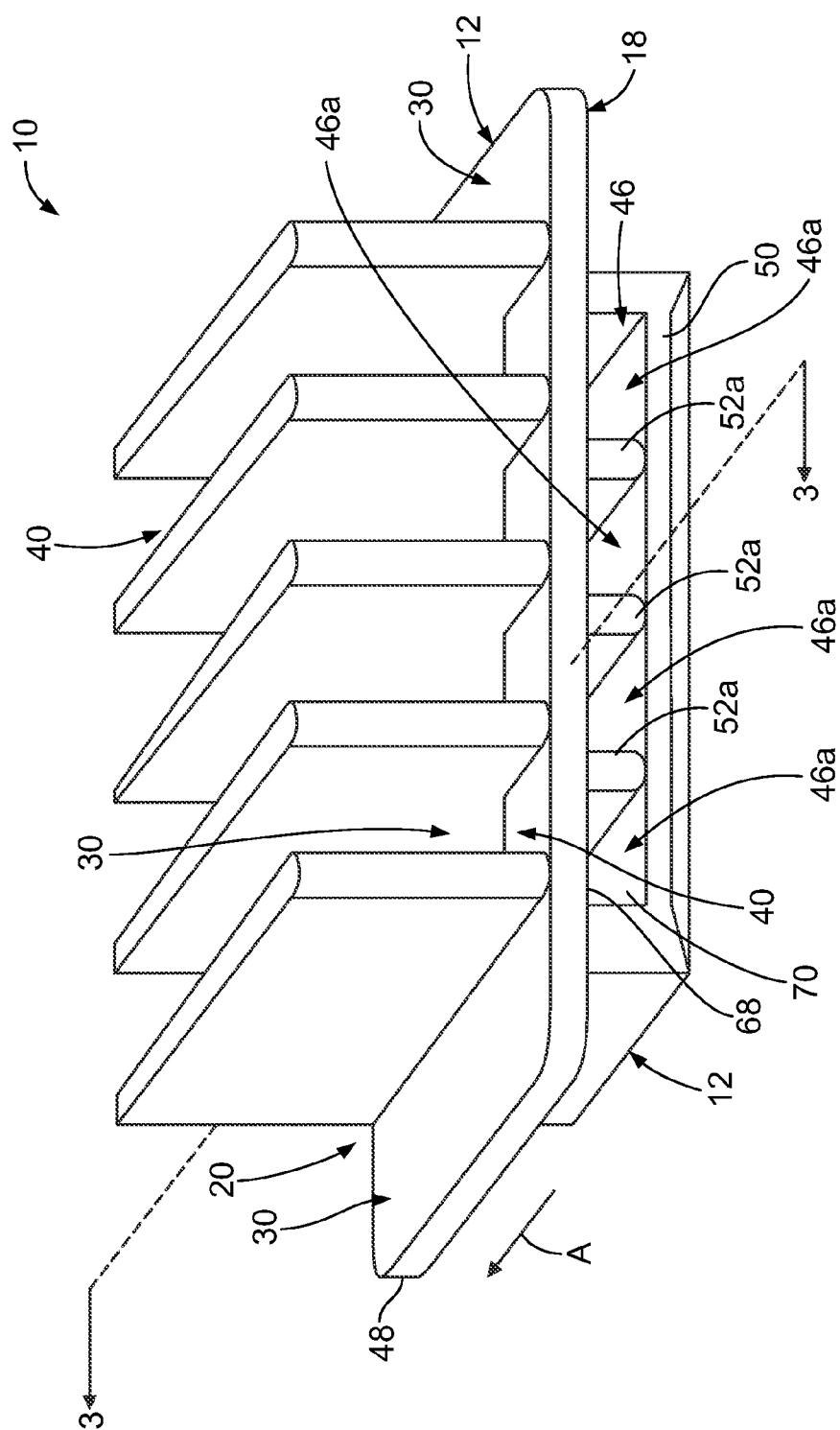


FIG. 2

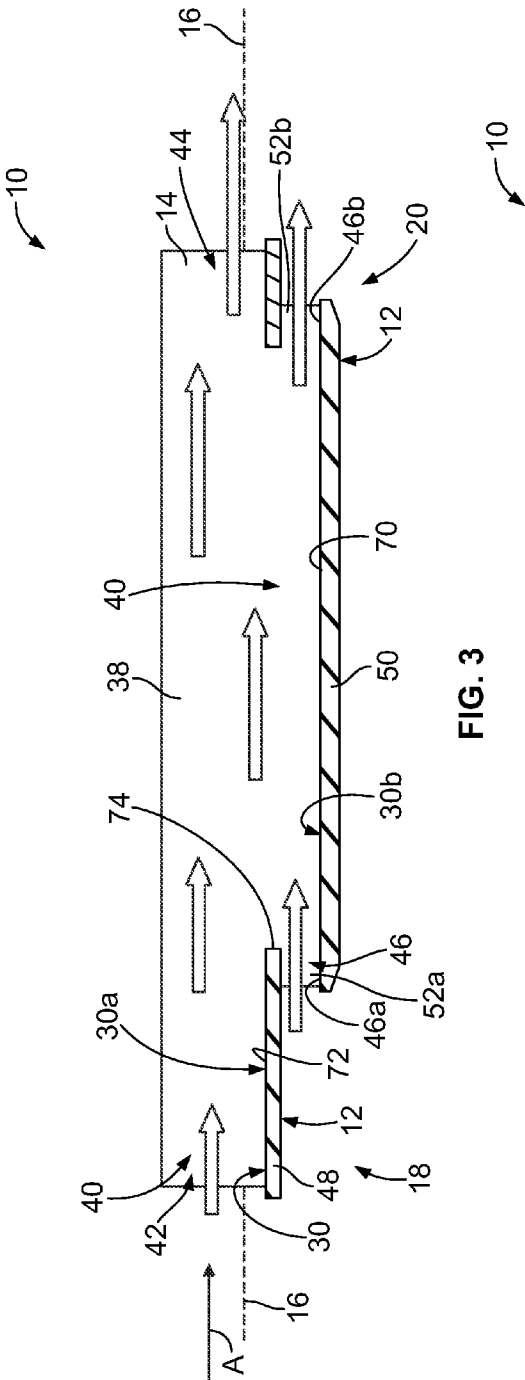


FIG. 3

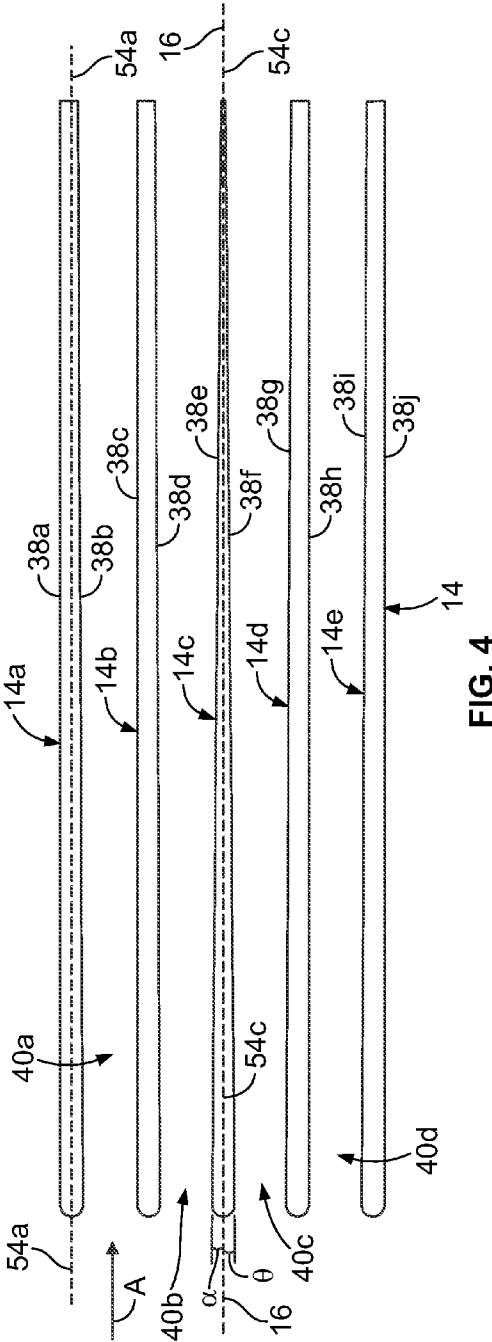


FIG. 4

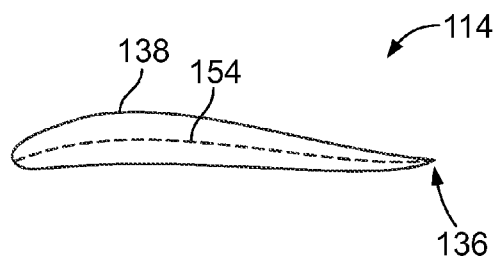


FIG. 5a

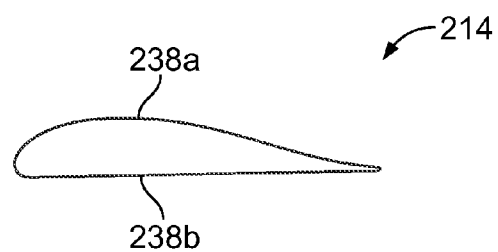


FIG. 5b

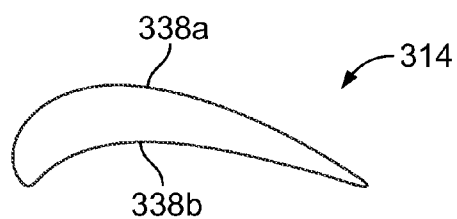


FIG. 5c

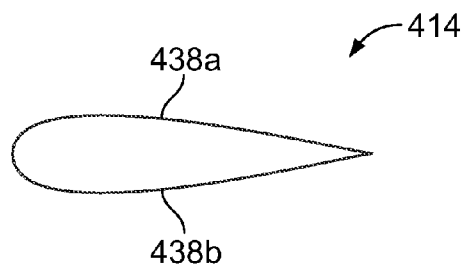


FIG. 5d

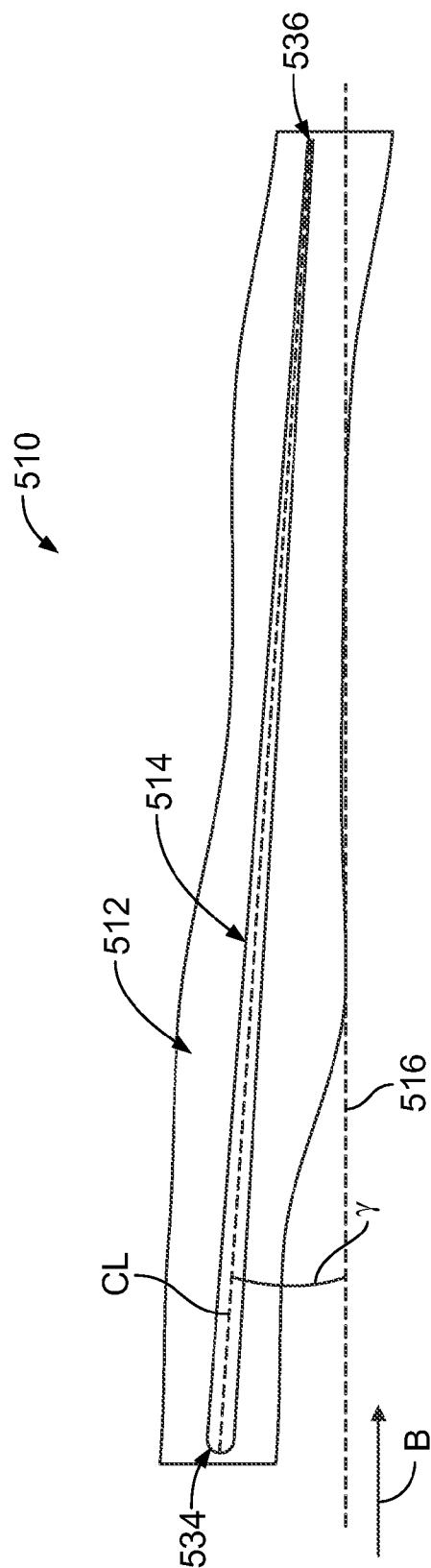


FIG. 6

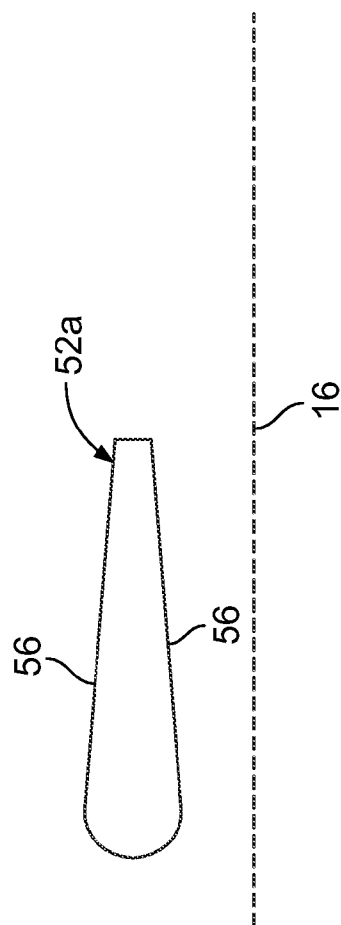


FIG. 7

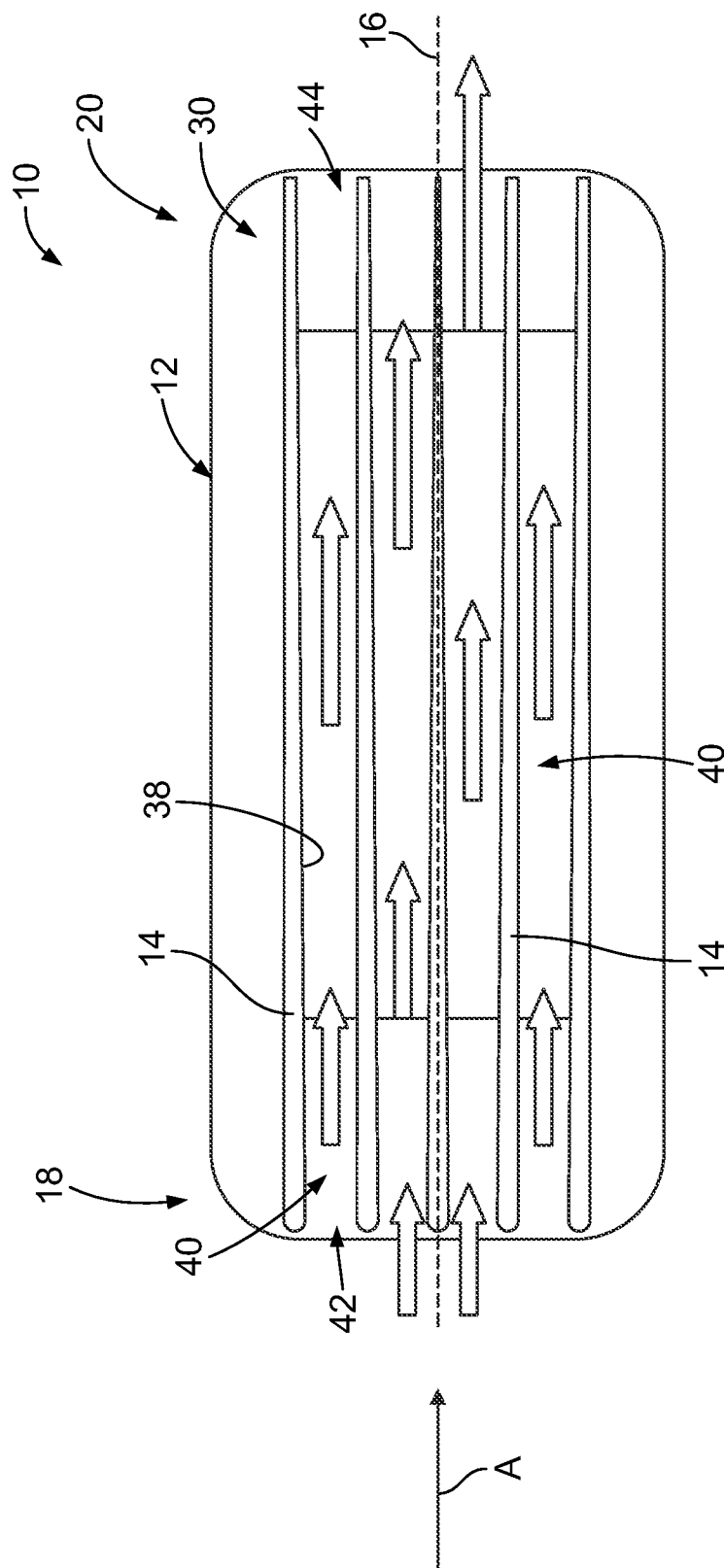


FIG. 8

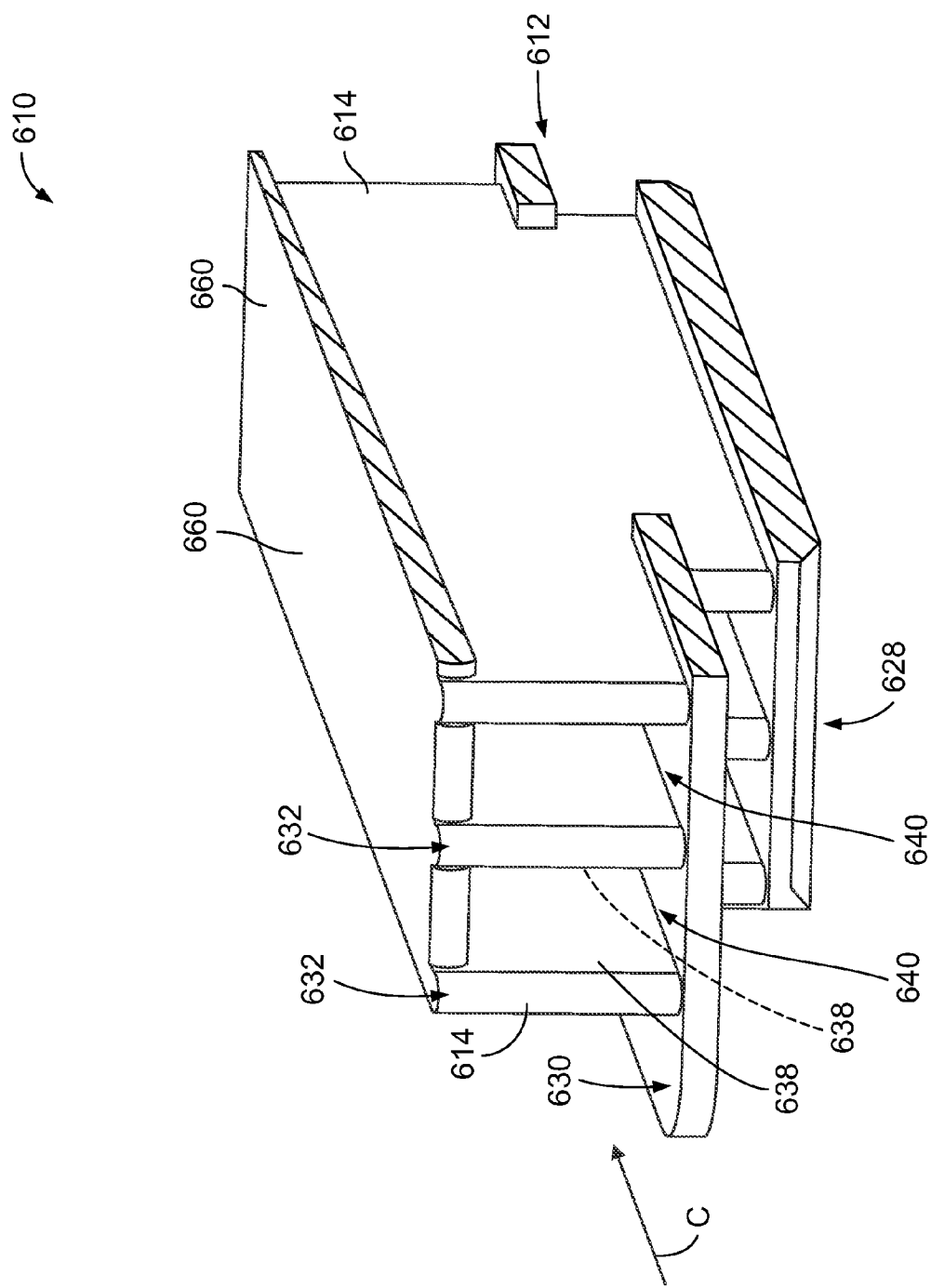


FIG. 9

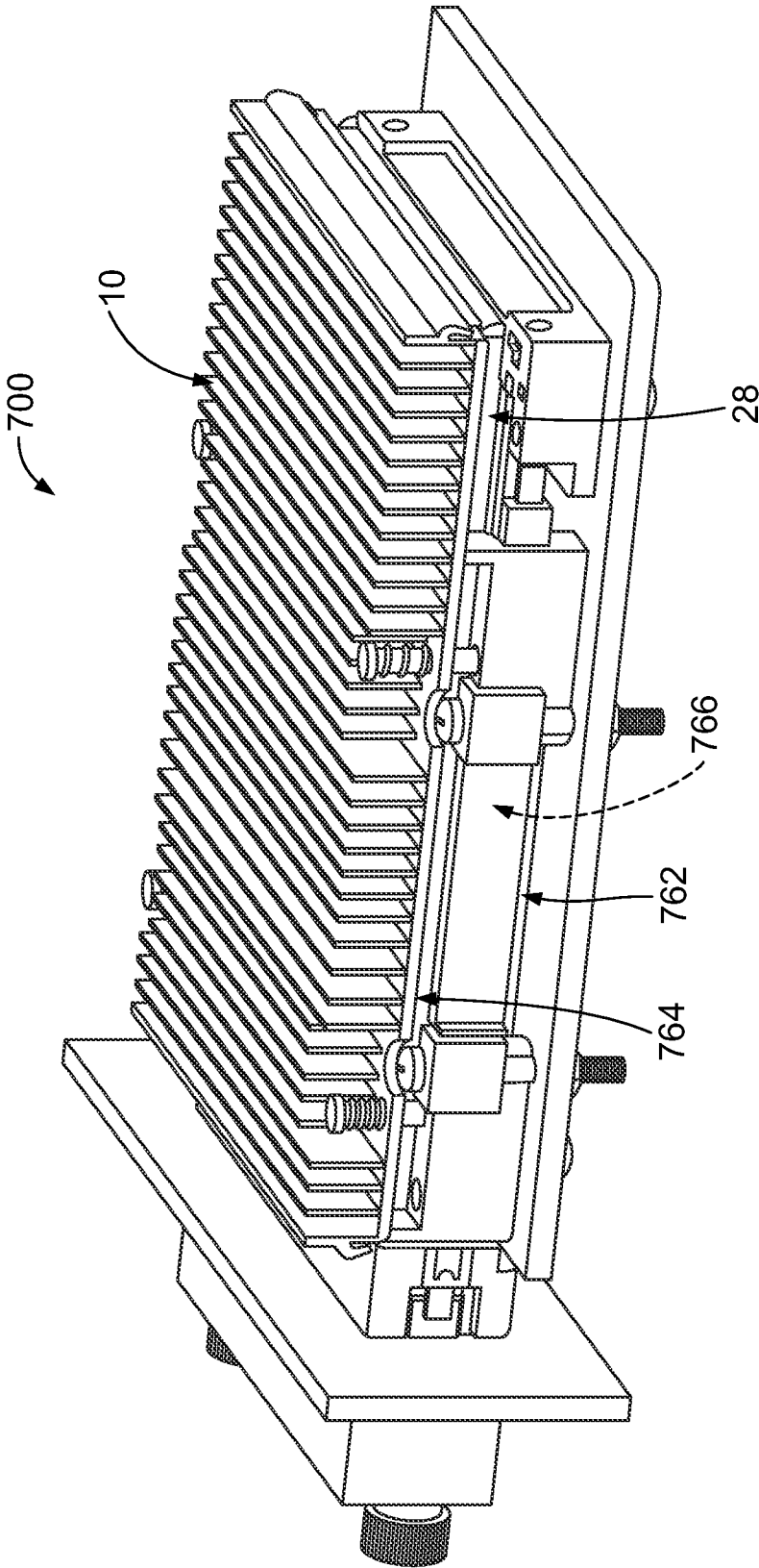


FIG. 10

HEAT SINK

BACKGROUND OF THE INVENTION

[0001] The subject matter described and/or illustrated herein relates generally to heat sinks.

[0002] The performance of many electrical components (e.g., pluggable modules sometimes referred to as “transceivers”) may be dependent upon the temperature at which the electrical component operates. Specifically, many electrical components generate heat during operation. The heat can build up to an extent that the operating temperature of an electrical component negatively affects the performance of the electrical component. For example, the speed at which a processor processes signals may be reduced when the processor operates at higher operating temperatures. Higher operating temperatures may also decrease the operational life of an electrical component. Accordingly, it may be desirable to cool an electrical component during operation thereof.

[0003] Heat sinks are often used to cool electrical components. A heat sink may include a base and one or more cooling fins that extend outward from the base. The base is mounted in thermal communication with the electrical component for absorbing heat from the electrical component. The heat sink may receive a flow of air that flows along the heat sink from a front end of the heat sink to a rear end of the heat sink. As the flow of air flows along the heat sink, the cooling fins dissipate heat from the base to the airflow. But, known heat sinks may not promote balanced heat transfer along the heat sink. For example, more or less heat may be dissipated to the flow of air at the front end of the heat sink as compared to at the rear end of the heat sink. Such unbalanced heat transfer may cause the electrical component to be unevenly cooled, which may cause one or more areas of the electrical component to be inadequately cooled.

[0004] There is a need for a heat sink that promotes more balanced heat transfer along the heat sink.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one embodiment, a heat sink includes a base having a structure side and an opposite environmental side. The structure side of the base is configured to thermally communicate with a structure for absorbing heat from the structure. A cooling fin extends a height outwardly from the environmental side of the base. The cooling fin extends a cord length along the base from a leading edge to a trailing edge of the cooling fin. The cooling fin includes the cross-sectional shape of an airfoil along at least a portion of the height of the cooling fin to increase the velocity of a flow of air along the cord length of the cooling fin.

[0006] In another embodiment, a receptacle assembly is provided for a pluggable module. The receptacle assembly includes a receptacle configured to receive the pluggable module therein, and a heat sink mounted to the receptacle. The heat sink includes a base having a structure side and an opposite environmental side. The structure side of the base is configured to thermally communicate with a structure for absorbing heat from the structure. The heat sink includes a cooling fin extending a height outwardly from the environmental side of the base. The cooling fin extends a cord length along the base from a leading edge to a trailing edge of the cooling fin. The cooling fin includes the cross-sectional shape

of an airfoil along at least a portion of the height of the cooling fin to increase the velocity of a flow of air along the cord length of the cooling fin.

[0007] In another embodiment, a heat sink includes a base having a structure side and an opposite environmental side. The structure side of the base is configured to thermally communicate with a structure for absorbing heat from the structure. A first cooling fin extends a height outwardly from the environmental side of the base. The first cooling fin includes the cross-sectional shape of an airfoil along at least a portion of the height of the first cooling fin. A second cooling fin extends a height outwardly from the environmental side of the base. A fluid channel is defined between the first and second cooling fins. The environmental side of the base defines a lower boundary of the fluid channel. A cap defines an upper boundary of the fluid channel. The cap includes the cross-sectional shape of an airfoil.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a perspective view of an exemplary embodiment of a heat sink.

[0009] FIG. 2 is another perspective view of the heat sink shown in FIG. 1 illustrating an exemplary embodiment of cooling ports of the heat sink.

[0010] FIG. 3 is a cross-sectional view of the heat sink shown in FIGS. 1 and 2 taken along line 3-3 of FIG. 2.

[0011] FIG. 4 is a cross-sectional view of the heat sink shown in FIGS. 1-3 taken along line 4-4 of FIG. 1 and illustrating exemplary embodiments of airfoil shapes of cooling fins of the heat sink.

[0012] FIGS. 5a-5d are cross-sectional views of other exemplary embodiments of airfoil shapes.

[0013] FIG. 6 is a plan view of a portion of another exemplary embodiment of a heat sink.

[0014] FIG. 7 is a cross-sectional view of an exemplary embodiment of a divider wall of the cooling ports shown in FIG. 2.

[0015] FIG. 8 is a top plan view of the heat sink shown in FIGS. 1-4.

[0016] FIG. 9 is a perspective view illustrating a cross section of another exemplary embodiment of a heat sink.

[0017] FIG. 10 is a perspective view of an exemplary embodiment of a connector assembly with which the heat sinks described and/or illustrated herein may be used.

DETAILED DESCRIPTION OF THE INVENTION

[0018] FIG. 1 is a perspective view of an exemplary embodiment of a heat sink 10. The heat sink 10 includes a base 12 and one or more cooling fins 14 that extend outward from the base 12. As will be described in more detail below, at least one of the cooling fins 14 includes the shape of an airfoil to increase the velocity of air flowing over the heat sink 10.

[0019] In the exemplary embodiment, the heat sink 10 has the general shape of a rectangle and extends a length along a central longitudinal axis 16 from a front end 18 to a rear end 20 that is opposite the front end 18. The heat sink 10 extends a width along a central latitudinal axis 22 from a side end 24 to an opposite side end 26 in the exemplary embodiment. The heat sink 10 is not limited to the rectangular shape shown herein. Rather, the heat sink 10 may additionally or alternatively include any other shape, such as, but not limited to, another rectangular shape (e.g., a square shape), a circular shape, an oval shape, shape having more than four sides, an

irregular shape, and/or the like. In embodiments wherein the heat sink 10 has a circular shape, the diameter of the circle may be considered the width and the length of the heat sink 10. The central longitudinal axis 16 and the central latitudinal axis 22 may each be referred to herein as a “central axis”.

[0020] The heat sink 10 includes the base 12, which extends from the front end 18 to the rear end 20 of the heat sink 10. The ends 18 and 20 of the heat sink 10 may be considered front and rear ends, respectively, of the base 12. In the exemplary embodiment, the base 12 extends a length along the central longitudinal axis 16 from the front end 18 to the rear end 20. Accordingly, the central longitudinal axis 16 extends approximately parallel to the length of the base 12. The ends 24 and 26 of the heat sink 10 may be considered side ends of the base 12. In the exemplary embodiment, the base 12 extends a width along the central latitudinal axis 22 from the side end 24 to the side end 26. Accordingly, the central latitudinal axis 22 extends approximately parallel to the width of the base 12.

[0021] The base 12 includes a structure side 28 and an opposite environmental side 30. During operation of the heat sink 10, air flows over the environmental side 30 of the base 12 such that heat is dissipated from the cooling fins 14 to the air via convection, as will be described below. The structure side 28 of the base 12 is configured to be connected in thermal communication with a structure (e.g., the pluggable module 764 shown in FIG. 10) for absorbing heat from the structure. The structure side 28 of the base 12 may be connected in thermal communication with the structure in any manner that enables the heat sink 10 to absorb heat from the structure. For example, the structure side 28 of the base 12 may be engaged with the structure to directly connect the base 12 and the structure in thermal communication, and/or a thermal interface material (not shown) may be engaged between the structure side 28 of the base 12 and the structure to indirectly connect the base 12 and the structure in thermal communication. The structure is not limited to being a pluggable module or another type of electrical component, but rather the heat sink 10 may be used with any structure from which it is desired to dissipate heat.

[0022] The cooling fins 14 extend outward from the environmental side 30 of the base 12. Each cooling fin 14 extends a height outward from the environmental side 30 of the base 12 to a tip 32 of the cooling fin 14. The cooling fins 14 include leading edges 34 and trailing edges 36. Each cooling fin 14 extends a cord length along the environmental side 30 of the base 12 from the leading edge 34 to the trailing edge 36 of the cooling fin 14. As used herein, the phrase “cord length” is intended to mean the linear distance between the leading edge and the trailing edge of a cooling fin. Each cooling fin 14 includes opposite sidewalls 38 that extend along the height and the cord length of the cooling fin 14. Although five are shown, the heat sink 10 may include any number of the cooling fins 14. Each of the cooling fins 14 may be referred to herein as a “first” anti/or a “second” cooling fin.

[0023] Optionally, the cord length of one or more of the cooling fins 14 is varied along the height of the cooling fin 14. For example, the cord length of one or more of the cooling fins 14 may be tapered along the height of the cooling fin 14 such that the cord length is smaller at the tip 32 of the cooling fin 14. Varying the cord length of one or more cooling fins 14 along the height of the cooling fin 14 may enhance the ability of the heat sink 10 to absorb heat from the structure, for example by increasing the ability of the cooling fin 14 to dissipate heat.

[0024] In the exemplary embodiment, the cord lengths of the cooling fins 14 extend along the length of the heat sink 10. Alternatively, the cord lengths of the cooling fins 14 extend along the width of the heat sink 10. By extending along the length or width of the heat sink 10, it is meant that the cord length of each cooling fin 14 extends at an approximately parallel or acute angle relative to the central longitudinal axis 16 or the central latitudinal axis 22, respectively (whether or not different cooling fins 14 extend at different angles relative to the axis 16 or 22).

[0025] As can be seen in FIG. 1, the cooling fins 14 are arranged side-by-side along the environmental side 30 of the base 12. The heat sink 10 includes fluid channels 40 defined between the cooling fins 14. Specifically, adjacent cooling fins 14 are spaced apart from each other along the environmental side 30 of the base 12 to define the corresponding fluid channel 40 therebetween. Adjacent cooling fins 14 include sidewalls 38 that face each other and define side boundaries of the corresponding fluid channel 40. The environmental side 30 of the base 12 defines lower boundaries of the fluid channels 40. Each fluid channel 40 extends a length from an entrance 42 that faces the front end 18 of the heat sink 10 to an exit 44 that faces the rear end 20 of the heat sink 10. As will be described below, air flowing over the environmental side 30 of the base 12 flows into the fluid channels 40 through the entrances 42, flows along the lengths of the fluid channels 40, and exits the fluid channels 40 through the exits 44. Although four are shown, the heat sink 10 may include any number of the fluid channels 40.

[0026] In the exemplary embodiment, and as illustrated in FIG. 1, the cord lengths of the cooling fins 14 extend along an approximate entirety of the length of the base 12. Alternatively, the cord length of one or more of the cooling fins 14 extends along only a portion of the length of the base 12. The cooling fins 14 may each have any height relative to the cord length of the cooling fin 14.

[0027] The heat sink 10 is not limited to the pattern of the cooling fins 14 shown herein. Rather, the pattern of the cooling fins 14 shown herein is meant as exemplary only. Examples of other patterns of the cooling fins 14 include, but are not limited to, patterns wherein at least one cooling fin 14 has a different height relative to at least one other cooling fin 14, patterns wherein at least one cooling fin 14 has a different cord length relative to at least one other cooling fin 14, patterns wherein at least one cooling fin 14 has a different location along the environmental side 30 of the base 14 relative to at least one other cooling fin 14 (whether or not the cord lengths of any cooling fins 14 overlap), and/or the like.

[0028] FIG. 2 is another perspective view of the heat sink 10. The heat sink 10 optionally includes one or more cooling ports 46 that extend through the base 12. In the exemplary embodiment, the base 12 includes an upper level 48 and a lower level 50 that is spaced apart along a height of the heat sink 10 from the upper level 48. The cooling ports 46 extend through the base 12 between the upper level 48 and the lower level 50. As will be described in more detail below, the cooling ports 46 intersect corresponding fluid channels 40 of the heat sink 10 such that the cooling ports 46 are fluidly interconnected with the corresponding fluid channels 40.

[0029] As shown in FIG. 2, the cooling ports 46 include cooling ports 46a that face the front end 18 of the heat sink 10. As will be described below and is shown in FIG. 3, the cooling ports 46 may include cooling ports 46b that face the rear end 20 of the heat sink 10. In the exemplary embodiment, the heat

sink 10 includes a plurality of the cooling ports 46a. Adjacent cooling ports 46a are separated by divider walls 52a that extend between, and interconnect, the upper level 48 and the lower level 50 of the base 12. Specifically, the divider walls 52a extend from a surface 68 of the upper level 48 to an opposing surface 70 of the lower level 50. As will be described below, one or more of the divider walls 52a optionally includes the shape of an airfoil. The heat sink 10 may include any number of the cooling ports 46a and any number of the divider walls 52a. The number of cooling ports 46a may or may not be equal to the number of fluid channels 40 of the heat sink 10.

[0030] FIG. 3 is a cross-sectional view of the heat sink 10 taken along line 3-3 of FIG. 2. Referring now to FIG. 3, the upper level 48 of the base 12 defines a segment 30a of the environmental side 30 of the base 12 and the lower level 50 defines another segment 30b of the environmental side 30 of the base 12. The segment 30b of the environmental side 30 includes the surface 70 of the lower level 50. As shown in FIG. 3, the cooling fins 14 extend outward from both segments 30a and 30b of the environmental side 30 of the base 12. In other words, the cooling fins 14 extend outward from both the surface 70 of the lower level 50 and from a surface 72 of the upper level 48. Although shown as extending along only a portion of the length of the heat sink 10, the lower level 50 of the base 12 may extend along an approximate entirety of the length of the heat sink 10 or along another amount of the length of the heat sink 10.

[0031] As described above, the cooling ports 46 may include cooling ports 46b that face the rear end 20 of the heat sink 10. In the exemplary embodiment, the heat sink 10 includes a plurality of the cooling ports 46b where adjacent cooling ports 46b are separated by divider walls 52b that extend between and interconnect the upper and lower levels 48 and 50, respectively, of the base 12. The heat sink 10 may include any number of the cooling ports 46b and any number of the divider walls 52b. The number of cooling ports 46b may or may not be equal to the number of fluid channels 40 and/or the number of cooling ports 46a. One or more of the divider walls 52b optionally includes the shape of an airfoil.

[0032] In the exemplary embodiment, each divider wall 52a and each divider wall 52b extends from a corresponding cooling fin 14, as can be seen in FIG. 3. In other words, the divider walls 52a and 52b are integral structures with corresponding cooling fins 14. Alternatively, one or more of the divider walls 52a and/or one or more of the divider walls 52b is a discrete structure from the corresponding cooling fin 14.

[0033] As shown in FIG. 3, the fluid channels 40 extend above the upper level 48 and the cooling ports 46a and 46b extend below the upper level 48. The base 12 includes one or more openings 74 that extend through the upper level 48. The cooling ports 46a and 46b intersect corresponding fluid channels 40 through the openings 74 such that the cooling ports 46a and 46b are fluidly interconnected with the corresponding fluid channels 40. The cooling ports 46a face the front end 18 of the heat sink 10 and provide entrances to the corresponding fluid channel 40. The cooling ports 46b face the rear end 20 of the heat sink 10 and provide exits to the corresponding fluid channel 40. As will be described below, air flowing over the environmental side 30 of the base 12 flows into the fluid channels 40 through the entrances 42 and through the cooling ports 46a. The air flows along the lengths of the fluid channels 40 and exits the fluid channels 40 through the exits 44 and through the cooling ports 46b.

[0034] FIG. 4 is a cross-sectional view of the heat sink 10 taken along line 4-4 of FIG. 1. As described above, at least one of the cooling fins 14 includes the shape of an airfoil to increase the velocity of air flowing over the heat sink 10. Specifically, at least one of the cooling fins 14 includes the cross-sectional shape of an airfoil along at least a portion of the height of the cooling fin 14. In the exemplary embodiment, all of the cooling fins 14 include the cross-sectional shape of an airfoil along at least a portion of the height thereof. But, any number of the cooling fins 14 may include the cross-sectional shape of an airfoil.

[0035] Each cooling fin 14 that includes the cross-sectional shape of an airfoil may include any airfoil shape that increases the velocity of air flowing along the cord length of the cooling fin 14. General examples of airfoil shapes of the cooling fins 14 include, but are not limited to, symmetric airfoils, cambered airfoils, reflexed camber airfoils, airfoils having one or more curved sides, airfoils having one or more planar sides, and/or the like. Each cooling fin 14 that includes the cross-sectional shape of an airfoil may include the airfoil shape along any amount and segment of the height thereof. In the exemplary embodiment, each cooling fin 14 includes the cross-sectional shape of an airfoil along an approximate entirety of the height of the cooling fin 14.

[0036] FIG. 4 illustrates exemplary airfoil shapes of the cooling fins 14. As shown in FIG. 4, some of the cooling fins 14 have different airfoil shapes than other cooling fins 14, and some of the cooling fins 14 have approximately the same airfoil shape as other cooling fins 14. Specifically, in the exemplary embodiment, cooling fins 14a, 14b, 14d, and 14e have approximately the same airfoil shape as each other, while a cooling fin 14c has an airfoil shape that is different than the airfoil shape of the cooling fins 14a, 14b, 14d, and 14e. In other embodiments, all of the cooling fins 14 have the same airfoil shape or each of the cooling fins 14 has a different airfoil shape than each other cooling fin 14.

[0037] Referring now to the cooling fin 14a, the airfoil shape of the cooling fin 14a extends along a camber line 54a. In other words, the cord length of the cooling fin 14a extends along the camber line 54a. The cooling fin 14a includes opposite sidewalls 38a and 38b that are approximately planar. The sidewall 38a extends approximately parallel to the central longitudinal axis 16 of the heat sink 10. The sidewall 38b extends non-parallel to the central longitudinal axis 16. The airfoil shape of the cooling fin 14a is an example of an airfoil that is asymmetrical about the camber line 54a, which is commonly referred to as a “cambered airfoil”. The sidewall 38b may extend at any non-parallel angle relative to the central longitudinal axis 16.

[0038] The cooling fin 14b is arranged adjacent the cooling fin 14a such that a fluid channel 40a is defined between the cooling fins 14a and 14b. The cooling fin 14b includes opposite sidewalls 38c and 38d that are approximately planar. The airfoil shape of the cooling fin 14b has the same shape and orientation as the airfoil shape of the cooling fin 14a. For example, the sidewall 38c extends approximately parallel to the central longitudinal axis 16 of the heat sink 10 and the sidewall 38d extends non-parallel to the central longitudinal axis 16. Moreover, the airfoil shapes of the cooling fins 14a and 14b have the same orientation such that the sidewalls 38a and 38c face in the same general direction and the sidewalls 38b and 38d face in the same general direction.

[0039] The cooling fin 14c is arranged adjacent the cooling fin 14b such that a fluid channel 40b is defined between the

cooling fins **14b** and **14c**. The airfoil shape of the cooling fin **14c** extends along a camber line **54c** and includes opposite sidewalls **38e** and **38f**, which are each approximately planar. Each of the sidewalls **38e** and **38f** extends at a non-parallel angle α and θ , respectively, to the central longitudinal axis **16** of the base **12**. In the exemplary embodiment, the angles α and θ have the same absolute value, but are different angles because the angle α is positive and the angle θ is negative. Accordingly, in the exemplary embodiment, the airfoil shape of the cooling fin **14c** is an example of an airfoil that is symmetrical about the camber line **54c**, which is commonly referred to as a “symmetrical airfoil”. The non-parallel angles α and θ of the sidewalls **38e** and **38f**, respectively, may each have any absolute value. In some alternative embodiments, the non-parallel angles α and θ of the sidewalls **38e** and **38f**, respectively, have different absolute values.

[0040] The cooling fin **14d** is arranged adjacent the cooling fin **14c** such that a fluid channel **40c** is defined between the cooling fins **14c** and **14d**. The cooling fin **14d** includes opposite sidewalls **38g** and **38h** that are approximately planar. The airfoil shape of the cooling fin **14d** has the same shape as the airfoil shape of the cooling fins **14a** and **14b**. For example, the sidewall **38g** extends non-parallel to the central longitudinal axis **16** of the heat sink **10** and the sidewall **38h** extends approximately parallel to the central longitudinal axis **16**. But, the airfoil shape of the cooling fin **14d** has a different orientation than the airfoil shapes of the cooling fins **14a** and **14b**. Specifically, the approximately planar sidewall **38h** of the cooling fin **14d** faces in the opposite general direction to the approximately planar sidewalls **38a** and **38c** of the cooling fins **14a** and **14b**, respectively.

[0041] The cooling fin **14e** is arranged adjacent the cooling fin **14d** such that a fluid channel **40d** is defined between the cooling fins **14d** and **14e**. The cooling fin **14e** includes opposite sidewalls **38i** and **38j** that are approximately planar. The airfoil shape of the cooling fin **14e** has the same shape and orientation as the airfoil shape of the cooling fin **14d**. For example, the sidewall **38i** extends non-parallel to the central longitudinal axis **16** of the heat sink **10** and the sidewall **38j** extends approximately parallel to the central longitudinal axis **16**. The airfoil shapes of the cooling fins **14d** and **14e** have the same orientation such that the sidewalls **38g** and **38i** face in the same general direction and the sidewalls **38h** and **38j** face in the same general direction.

[0042] FIGS. **5a-5d** are cross-sectional views of other exemplary embodiments of airfoil shapes of the cooling fins **14**. Specifically, FIG. **5a** illustrates a cooling fin **114** that includes a cross-sectional airfoil shape having a camber line **154** that curves back towards a sidewall **138** of the cooling fin **114** adjacent a trailing edge **136** of the cooling fin **114**, which is commonly referred to as a “reflexed camber airfoil”. FIG. **5b** illustrates a cooling fin **214** that includes a cross-sectional airfoil shape having a curved sidewall **238a** and an opposite sidewall **238b** that is approximately planar. FIG. **5c** illustrates a cooling fin **314** having opposite sidewalls **338a** and **338b** that are each curved. The sidewalls **338a** and **338b** have different curvatures. For example, the sidewall **338a** has a convex curvature, while the sidewall **338b** has a concave curvature. In some embodiments, the curvatures of the sidewalls **338a** and **338b** have different values, whether or not the sidewalls **338a** and **338b** are both concave, are both convex, or one is concave and the other is convex. The cooling fin **314** is another example of a cambered airfoil. FIG. **5d** illustrates a cooling fin **414** that includes the cross-sectional airfoil shape

having opposite sidewalls **438a** and **438b** that are each curved. The sidewalls **438a** and **438b** have approximately the same curvature such that the cooling fin **414** is another example of a symmetrical airfoil.

[0043] Referring again to FIG. **4**, in the exemplary embodiment, the cord length of each of the cooling fins **14a-e** extends approximately parallel to the central longitudinal axis **16** of the heat sink **10**. Accordingly, each of the cooling fins **14a-e** has an angle of attack that extends approximately parallel to a direction (indicated by the arrow A in FIG. **4**) of air flow along the heat sink **10**. Alternatively, the cord length of one or more of the cooling fins **14a-e** extends non-parallel to the central longitudinal axis **16** of the heat sink **10** such that the cooling fin **14** has an angle of attack that extends non-parallel to the direction A of air flow along the heat sink **10**. For example, FIG. **6** is a plan view of a portion of another exemplary embodiment of a portion of a heat sink **510**. The heat sink **510** includes a base **512** and a cooling fin **514** that extends outward from the base **512**. The cooling fin **514** extends a cord length CL from a leading edge **534** to a trailing edge **536** of the cooling fin **514**. The cord length CL of the cooling fin **514** extends at a non-parallel angle γ relative to a central longitudinal axis **516** of the heat sink **510**. Accordingly, the cooling fin **514** has an angle of attack that extends non-parallel to a direction of air flow (indicated by the arrow B) along the heat sink **510**. The angle γ of attack may have any value.

[0044] Referring again to FIGS. **2** and **3**, as described above, one or more of the divider walls **52a** and/or **52b** optionally includes the shape of an airfoil along at least a portion of the height thereof. The divider walls **52b** are not shown in FIG. **2**. In the exemplary embodiment, all of the divider walls **52a** and **52b** include the cross-sectional shape of an airfoil. But, any number of the divider walls **52a** and any number of the divider walls **52b** may include the cross-sectional shape of an airfoil. Each divider wall **52a** and/or **52b** that includes the cross-sectional shape of an airfoil may include any airfoil shape that increases the velocity of air flowing along the divider wall. General examples of airfoil shapes of the divider walls **52a** and/or **52b** include, but are not limited to, symmetric airfoils, cambered airfoils, reflexed camber airfoils, airfoils having one or more curved sides, airfoils having one or more planar sides, and/or the like. It should be understood that the exemplary airfoil shapes shown and/or described herein with respect to the cooling fins **14** are applicable to the divider walls **52a** and **52b**. Each divider wall **52a** and/or **52b** that includes the cross-sectional shape of an airfoil may include the airfoil shape along any amount and segment of the height thereof. In the exemplary embodiment, each divider wall **52a** and **52b** includes the cross-sectional shape of an airfoil along an approximate entirety of the height of the divider wall.

[0045] In the exemplary embodiment, each of the divider walls **52a** and **52b** has an angle of attack that extends approximately parallel to the direction A of air flow along the heat sink **10**. Alternatively, one or more of the divider walls **52a** and/or **52b** has an angle of attack that extends non-parallel to the direction A of air flow along the heat sink **10**.

[0046] FIG. **7** is a cross-sectional view of one of the divider walls **52a** illustrating the divider wall **52a** including an exemplary embodiment of the cross-sectional shape of an airfoil. The airfoil shape of the divider wall **52a** includes opposite sidewalls **56**, which are each approximately planar in the exemplary embodiment. Each of the sidewalls **56** extends at a

non-parallel angle relative to the central longitudinal axis 16. The airfoil shape of the divider wall 52a is an example of symmetrical airfoil.

[0047] FIG. 8 is a top plan view of the heat sink 10. Referring now to FIGS. 3 and 8, during operation of the heat sink 10, air flows over the environmental side 30 of the base 12 in the direction A. In the exemplary embodiment, the direction A of air flowing over the heat sink 10 is approximately parallel to the central longitudinal axis 16 of the heat sink 10 such that the air flows along the length of the heat sink 10. Alternatively, the direction A of air flowing over the heat sink 10 is approximately parallel to the central latitudinal axis 22 (FIG. 1) of the heat sink 10 such that the air flows along the width of the heat sink 10, for example in embodiments wherein the cord lengths of the cooling fins 14 extend along the width of the heat sink 10.

[0048] Air flowing in the direction A flows into the fluid channels 40 through the entrances 42. Air flowing in the direction A also flows into the fluid channels 40 through the cooling ports 46a (not visible in FIG. 8). The air flows along the lengths of the fluid channels 40 and exits the fluid channels 40 through the exits 44 and through the cooling ports 46b (not visible in FIG. 8). As the air flows over the sidewalls 38 along the cord lengths of the cooling fins 14, the airfoil shapes of the cooling fins 14 increase the velocity of the air flow along the cooling fins 14. In other words, the airfoil shapes of the cooling fins 14 increase the velocity of air flowing through the fluid channels 40. Moreover, as the air flows through the cooling ports 46 and over the divider walls 52a and 52b (not visible in FIG. 8), the airfoil shapes of the divider walls 52a and 52b increase the velocity of the air flow through the cooling ports 46.

[0049] The increased velocity of the airflow may promote a more balanced heat transfer along the heat sink 10 as compared to at least some known heat sinks. For example, the increased velocity of the airflow may bring the amount of heat dissipated at the front end 18 of the heat sink 10 closer to the amount of heat dissipated at the rear end 20, or vice versa, as compared to at least some known heat sinks. Moreover, and for example, the increased velocity of the airflow may reduce the air pressure at the rear end 20 of the heat sink 10, which may facilitate drawing air into the front end 18 of the heat sink in a greater amount and/or at a greater velocity. In other words, the increased velocity of the airflow may create a relatively low pressure zone at the rear end 20 of the heat sink 10 that facilitates increasing the amount and/or rate of airflow over the heat sink 10 and thereby promotes better heat transfer. Moreover, and for example, the increased velocity of the airflow through the cooling ports 46 may create a relatively low pressure zone at the cooling ports 46a and/or 46b, which may facilitate increasing the amount and/or rate of airflow through the fluid channels 40 and thereby promote better heat transfer. Further, the increased velocity of the airflow along the cord lengths of the cooling fins 14 may increase an overall amount of heat dissipated by the heat sink 10 by increasing the amount of heat dissipated by the cooling fins 14 to the air.

[0050] Various parameters of the heat sink 10 may be selected to provide the heat sink with a predetermined heat transfer performance. For example, various parameters of the heat sink 10 may be selected to provide a predetermined air flow velocity and/or pressure differential from the front end 18 to the rear end 20 of the heat sink 10. Examples of the various parameters of the heat sink 10 that may be selected to provide the heat sink with a predetermined heat transfer per-

formance include, but are not limited to, the size of the fluid channels, the size of the cooling ports 46, the particular airfoil size and/or shape of one or more of the cooling fins 14, one or more of the divider walls 52a and/or 52b, and/or one or more of the caps 660 (shown in FIG. 9 and described below), the particular angle of attack of one or more of the cooling fins 14, one or more of the divider walls 52a and/or 52b, and/or one or more of the caps 660, and/or the like. One example of selecting a particular airfoil shape of the cooling fins 14 includes providing a sidewall 38 with a relatively great amount of curvature that may promote increased turbulence.

[0051] FIG. 9 is a perspective view illustrating a cross section of another exemplary embodiment of a heat sink 610. The heat sink 610 includes a base 612 and one or more cooling fins 614 that extend outward from the base 612. At least one of the cooling fins 614 includes the shape of an airfoil. The base 612 includes a structure side 628 and an opposite environmental side 630.

[0052] The cooling fins 614 extend outward from the environmental side 630 of the base 612. Each cooling fin 614 extends a height outward from the environmental side 630 of the base 612 to a tip 632 of the cooling fin 614. The heat sink 610 includes one or more fluid channels 640 defined between the cooling fins 614. Sidewalls 638 of adjacent cooling fins 614 that face each other define side boundaries of the fluid channels 640. The environmental side 630 of the base 612 defines lower boundaries of the fluid channels 640. Each of the cooling fins 614 may be referred to herein as a “first” and/or a “second” cooling fin.

[0053] The heat sink 610 includes one or more caps 660 that extend over the tips 632 of the cooling fins 614 and define upper boundaries of the fluid channels 640. Any number of the fluid channels 640 may be covered by a cap 660 that defines an upper boundary of the fluid channel 640. Moreover, the heat sink 610 may include one or more caps 660 that is a single structure that defines a boundary of two or more fluid channels 640, and/or the heat sink 610 may include one or more caps 660 that only defines the upper boundary of a single fluid channel 640. The heat sink 610 may include any number of caps 660.

[0054] Each cap 660 of the heat sink 610 optionally includes the cross-sectional shape of an airfoil. Any number of caps 660 may include the cross-sectional shape of an airfoil. Each cap 660 that includes the cross-sectional shape of an airfoil may include any airfoil shape that increases the velocity of air flowing within the corresponding fluid channel (s) 640. General examples of airfoil shapes of a cap 660 include, but are not limited to, symmetric airfoils, cambered airfoils, reflexed camber airfoils, airfoils having one or more curved sides, airfoils having one or more planar sides, and/or the like. It should be understood that the exemplary airfoil shapes shown and/or described herein with respect to the cooling fins 614 are applicable to the caps 660. Each cap 660 that includes the cross-sectional shape of an airfoil may include the airfoil shape along any amount and segment of the span thereof. In the exemplary embodiment, each cap 660 includes the cross-sectional shape of an airfoil along an approximate entirety of the span of the cap 660.

[0055] In the exemplary embodiment, each cap has an angle of attack that extends approximately parallel to a direction C of air flow along the heat sink 610. Alternatively, one or more of the caps 610 has an angle of attack that extends non-parallel to the direction C of air flow along the heat sink 610.

[0056] FIG. 10 is a perspective view of an exemplary embodiment of a connector assembly 700 with which the heat sinks described and/or illustrated herein (e.g., the heat sink 10 shown in FIGS. 1-4 and 8) may be used. The heat sinks described and/or illustrated herein are not limited to being used with the connector assembly 700 or connector assemblies generally. Rather, the heat sinks described and/or illustrated herein may be used with any structure from which it is desired to dissipate heat.

[0057] The connector assembly 700 includes a receptacle assembly 762 and a pluggable module 764. The receptacle assembly 762 includes a receptacle 766 that receives the pluggable module 764 therein. The heat sink 10 is mounted to the receptacle assembly 762 such that the structure side 28 of the heat sink 10 faces the pluggable module 764 when the pluggable module 764 is received within the receptacle 766. When the pluggable module 764 is received within the receptacle 766, the heat sink 10 thermally communicates with the pluggable module 764 to dissipate heat from the pluggable module 764 to the environment.

[0058] The embodiments described and/or illustrated herein may provide a heat sink having a more balanced heat transfer along the heat sink 10 as compared to at least some known heat sinks.

[0059] It is to be understood that the above description and the figures are intended to be illustrative, and not restrictive. For example, the above-described and/or illustrated embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the subject matter described and/or illustrated herein without departing from its scope. Dimensions, types of materials, orientations of the various components (including the terms “upper”, “lower”, “vertical”, and “lateral”), and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description and the figures. The scope of the subject matter described and/or illustrated herein should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112, sixth paragraph, unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function void of further structure.

What is claimed is:

1. A heat sink comprising:

a base having a structure side and an opposite environmental side, the structure side of the base being configured to thermally communicate with a structure for absorbing heat from the structure; and

a cooling fin extending a height outwardly from the environmental side of the base, the cooling fin extending a cord length along the base from a leading edge to a

trailing edge of the cooling fin, the cooling fin comprising the cross-sectional shape of an airfoil along at least a portion of the height of the cooling fin to increase the velocity of a flow of air along the cord length of the cooling fin.

2. The heat sink of claim 1, wherein the base extends from a front end to a rear end, the flow of air flows along the base from the front end to the rear end, and the airfoil shape of the cooling fin is configured to reduce a pressure at the rear end of the base.

3. The heat sink of claim 1, wherein the cooling fin is configured to increase the velocity of the flow of air through a channel defined between the cooling fin and another cooling fin of the heat sink.

4. The heat sink of claim 1, wherein the cooling fin is a first cooling fin, the heat sink comprising a second cooling fin that extends a height outwardly from the environmental side of the base, the first and second cooling fins being spaced apart along the environmental side of the base to define a fluid channel therebetween.

5. The heat sink of claim 1, wherein the cooling fin is a first cooling fin, the heat sink comprising a second cooling fin that extends a height outwardly from the environmental side of the base, the first and second cooling fins being spaced apart along the environmental side of the base to define a fluid channel therebetween, the second cooling fin comprising the cross-sectional shape of an airfoil along at least a portion of the height of the second cooling fin.

6. The heat sink of claim 1, wherein the airfoil shape of the cooling fin extends along a camber line, the airfoil shape of the cooling fin being asymmetrical about the camber line.

7. The heat sink of claim 1, wherein the base extends along a central axis that extends approximately parallel to a length or a width of the base, the cooling fin comprising opposite sidewalls that extend along the height of the cooling fin, at least one of sidewalls extending non-parallel relative to the central axis of the base.

8. The heat sink of claim 1, wherein the cooling fin comprising opposite sidewalls that extend along the height of the cooling fin, the sidewalls comprising curvatures that are different than each other.

9. The heat sink of claim 1, wherein the base extends along a central axis that extends approximately parallel to a length or a width of the base, the cooling fin comprising opposite sidewalls that extend along the height of the cooling fin, the sidewalls comprising approximately planar shapes that have different angles relative to the central axis of the base.

10. The heat sink of claim 1, wherein the base comprises a cooling port that extends through the base, the cooling port being defined by a divider wall that comprises the cross-sectional shape of an airfoil.

11. The heat sink of claim 1, wherein the cooling fin is a first cooling fin, the heat sink comprising a second cooling fin, the first and second cooling fins defining a fluid channel therebetween, the environmental side of the base defining a boundary of the fluid channel, the heat sink further comprising a cap that defines a boundary of the fluid channel that is opposite the boundary defined by the environmental side of the base, wherein the cap comprises the cross-sectional shape of an airfoil.

12. The heat sink of claim 1, wherein the base extends along a central axis that extends approximately parallel to a length or a width of the base, the cord length of the cooling fin extending non-parallel to the central axis of the base.

13. The heat sink of claim 1, wherein the cord length of the cooling fin is varied along the height of the cooling fin.

14. A receptacle assembly for a pluggable module, said receptacle assembly comprising:

a receptacle configured to receive the pluggable module therein; and

a heat sink mounted to the receptacle, the heat sink comprising:

a base having a structure side and an opposite environmental side, the structure side of the base being configured to thermally communicate with a structure for absorbing heat from the structure; and

a cooling fin extending a height outwardly from the environmental side of the base, the cooling fin extending a cord length along the base from a leading edge to a trailing edge of the cooling fin, the cooling fin comprising the cross-sectional shape of an airfoil along at least a portion of the height of the cooling fin to increase the velocity of a flow of air along the cord length of the cooling fin.

15. The receptacle assembly of claim 14, wherein the base of the heat sink extends from a front end to a rear end, the flow of air flows along the base from the front end to the rear end, and the airfoil shape of the cooling fin is configured to reduce a pressure at the rear end of the base.

16. The receptacle assembly of claim 14, wherein the airfoil shape of the cooling fin extends along a camber line, the airfoil shape of the cooling fin being asymmetrical about the camber line.

17. The receptacle assembly of claim 14, wherein the base of the heat sink extends along a central axis that extends

approximately parallel to a length or a width of the base, the cooling fin comprising opposite sidewalls that extend along the height of the cooling fin, at least one of sidewalls extending non-parallel relative to the central axis of the base.

18. The receptacle assembly of claim 14, wherein the cooling fin of the heat sink has an angle of attack that extends non-parallel to a direction of air flow along the environmental side of the base.

19. The receptacle assembly of claim 14, wherein the cord length of the cooling fin is varied along the height of the cooling fin.

20. A heat sink comprising:

a base having a structure side and an opposite environmental side, the structure side of the base being configured to thermally communicate with a structure for absorbing heat from the structure;

a first cooling fin extending a height outwardly from the environmental side of the base, the first cooling fin comprising the cross-sectional shape of an airfoil along at least a portion of the height of the first cooling fin;

a second cooling fin extending a height outwardly from the environmental side of the base;

a fluid channel defined between the first and second cooling fins, the environmental side of the base defining a lower boundary of the fluid channel; and

a cap defining an upper boundary of the fluid channel, wherein the cap comprises the cross-sectional shape of an airfoil.

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