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STORAGE DEVICE COOLING AIR VENTILATION FEATURES

Abstract

In the context of an electronic device such as a solid-state storage drive, use of an enclosure cover including an inlet port through a first lateral sidewall and a corresponding cooling duct coincident with first inlet port enables directing of airflow laterally to below the cover to a printed circuit board housed therein. To further augment device cooling within specification-dictated restrictions, a row of ventilation slots may be used for directing additional lateral airflow over the outer surface of the cover. Still further, interfacing tooth structures in the cover and corresponding base enable cost-effective end-to-end airflow through the device by avoiding machining steps during manufacturing, while still mitigating risk of electrostatic discharge.

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Background/Summary

FIELD OF EMBODIMENTS

[0001] Embodiments of the invention may relate generally to electronic devices such as solid-state storage devices, and particularly to cooling air ventilation features.

BACKGROUND

[0002] Enterprise solid-state storage devices, or solid-state drives (SSDs), are commonly used in client, hyperscale and enterprise compute environments. Since SSDs are made from flash memory (e.g., NAND (NOT AND) flash memory), they can be built in many different form factors and are typically associated with industry standard form factors and corresponding specifications and protocols. For example, a family of specifications referred to as Enterprise and Datacenter Standard Form Factor (EDSFF) were developed to address the concerns of data center storage. For example, EDSFF E3 is a family of form factors designed to update and replace the traditional U.2 2.5-inch form factor in servers and storage systems, and were largely designed for future servers and storage systems. The primary usage of E3 is for SSDs and/or storage class memory, but E3 is big enough to accommodate a broader range of device types (for non-limiting examples, accelerators or network interface cards). It is well-known that electronic devices generally and SSDs in particular dissipate power in the form of heat, which requires significant cooling and related costs.

[0003] Any approaches that may be described in this section are approaches that could be pursued, but not necessarily approaches that have been previously conceived or pursued. Therefore, unless otherwise indicated, it should not be assumed that any of the approaches described in this section qualify as prior art merely by virtue of their inclusion in this section.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Embodiments are illustrated by way of example, and not by way of limitation, in the figures of the accompanying drawings and in which like reference numerals refer to similar elements and in which:

[0005] FIG. **1** is a block diagram illustrating a solid-state drive (SSD), according to an embodiment;

[0006] FIG. **2**A is a perspective view illustrating SSD device cooling duct features, according to an embodiment;

[0007] FIG. **2**B is a perspective view illustrating SSD device cooling duct features, according to an embodiment;

[0008] FIG. **3**A is a top perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0009] FIG. **3**B is a top perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0010] FIG. **3**C is a bottom perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0011] FIG. **3**D is a bottom perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0012] FIG. **4**A is a perspective view illustrating a bottom base of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0013] FIG. **4**B is a perspective view illustrating a bottom base of SSD device of FIGS. **2**A-**2**B, according to an embodiment;

[0014] FIG. **5**A is a perspective view illustrating an SSD device assembly defining cross-sections, according to an embodiment;

[0015] FIG. **5**B is a first cross-sectional perspective view illustrating the SSD device assembly of

FIG. **5**A, according to an embodiment;
[0016] FIG. **5**C is a second cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, according to an embodiment;
[0017] FIG. **5**D is a third cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, according to an embodiment;
[0018] FIG. **5**E is a fourth cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, according to an embodiment;
[0019] FIG. **6** is a perspective view illustrating an SSD device assembly with cooling ventilation features, according to an embodiment;
[0020] FIG. **7**A is a perspective view illustrating a top cover of SSD device of FIG. **6**, according to an embodiment;
[0021] FIG. **7**B is a perspective view illustrating the top cover of SSD device of FIG. **6**, according to an embodiment;
[0022] FIG. **8**A is a perspective view illustrating a bottom base of SSD device of FIG. **6**, according to an embodiment;
[0023] FIG. **8**B is a perspective view illustrating the bottom base of SSD device of FIG. **6**, according to an embodiment;
[0024] FIG. **9**A is a perspective view illustrating a first end of an SSD device assembly with cooling ventilation features, according to an embodiment;
[0025] FIG. **9**B is a perspective view illustrating a second end of an SSD device assembly with cooling ventilation features, according to an embodiment;
[0026] FIG. **10**A is a perspective view illustrating the first end of a top cover of SSD device assembly of FIGS. **9**A-**9**B, according to an embodiment;
[0027] FIG. **10**B is a perspective view illustrating the second end of the top cover of SSD device assembly of FIGS. **9**A-**9**B, according to an embodiment;
[0028] FIG. **11**A is a perspective view illustrating the first end of a bottom base of SSD device assembly of FIGS. **9**A-**9**B, according to an embodiment;
[0029] FIG. **11**B is a perspective view illustrating the second end of the bottom base of SSD device assembly of FIGS. **9**A-**9**B, according to an embodiment;
[0030] FIG. **12**A is an end perspective view illustrating a solid-state storage device, according to an embodiment;
[0031] FIG. **12**B is a side perspective view illustrating the solid-state storage device of FIG. **12**A, according to an embodiment;
[0032] FIG. **12**C is a cross-sectional perspective view illustrating the solid-state storage device of FIG. **12**A, according to an embodiment; and
[0033] FIG. **13** is a flow diagram illustrating a method of assembling a data storage device, according to an embodiment.

DETAILED DESCRIPTION

[0034] Generally, approaches to electronic device cooling air ventilation features, such as for solid-state drives, are described. In the following description, for the purposes of explanation, numerous specific details are set forth to provide a thorough understanding of the embodiments of the invention described herein. It will be apparent, however, that the embodiments of the invention described herein may be practiced without these specific details. In other instances, well-known structures and devices may be shown in block diagram form to avoid unnecessarily obscuring the embodiments of the invention described herein.

INTRODUCTION

Terminology

[0035] References herein to “an embodiment”, “one embodiment”, and the like, are intended to mean that the particular feature, structure, or characteristic being described is included in at least one embodiment of the invention. However, instances of such phrases do not necessarily all refer to the same embodiment,

[0036] The term "substantially" will be understood to describe a feature that is largely or nearly structured, configured, dimensioned, etc., but with which manufacturing tolerances and the like may in practice result in a situation in which the structure, configuration, dimension, etc. is not always or necessarily precisely as stated. For example, describing a structure as "substantially vertical" would assign that term its plain meaning, such that the sidewall is vertical for all practical purposes but may not be precisely at 90 degrees throughout.

[0037] While terms such as "optimal", "optimize", "minimal", "minimize", "maximal", "maximize", and the like may not have certain values associated therewith, if such terms are used herein the intent is that one of ordinary skill in the art would understand such terms to include affecting a value, parameter, metric, and the like in a beneficial direction consistent with the totality of this disclosure. For example, describing a value of something as "minimal" does not require that the value actually be equal to some theoretical minimum (e.g., zero), but should be understood in a practical sense in that a corresponding goal would be to move the value in a beneficial direction toward a theoretical minimum.

Context

[0038] Recall that enterprise storage solutions such as solid-state drives (SSDs) are commonly used in client, hyperscale and enterprise compute environments, and that a family of specifications referred to as Enterprise and Datacenter Standard Form Factor (EDSFF) were developed to address the concerns of data center storage. Furthermore, the specifications for the EDSFF E3 (or simply "E3") family of form factors set forth constraints related to various structures corresponding to an E3 storage device, such as what portions of a device sidewall must be reserved for grounding surfaces and riding surfaces (e.g., related to device handling/installation). In view of the cooling needs of an SSD, and further in view of the limited structural space available for cooling features on an SSD, efficiently and inexpensively cooling an SSD remains a challenge, especially in the context of high-velocity airflow such as in high-performance datacenter and server systems.

Electronic Storage Device Cooling Features

[0039] FIG. **2**A is a perspective view illustrating SSD device cooling duct features, and FIG. **2**B is a perspective view illustrating SSD device cooling duct features, both according to embodiments. An electronic storage device such as illustrated storage device **200** is configured to comprise one or more printed circuit board (PCB) (PCB **210** of FIGS. **5**B-**5**E; see also, e.g., the components of SSD **152** of FIG. **1**) within a device enclosure described hereafter. According to an embodiment, storage device **200** comprises a PCB including non-volatile memory. Similarly, and according to an embodiment, storage device **200** comprises a PCB including NAND (NOT AND) flash memory. Furthermore, and according to an embodiment, storage device **200** is a solid-state drive (SSD) storage device (see, e.g., SSD **152** of FIG. **1**).

[0040] Storage device **200** comprises an enclosure cover **202** ("cover **202**") coupled to an enclosure base **204** ("base **204**"). According to an embodiment, cover **202** comprises a first inlet port **202*p*-1** through a first lateral sidewall **202*s*-1** and a first cooling duct **202*d*-1** at least in part coincident with the first inlet port **202*p*-1**, where the first cooling duct **202*d*-1** is configured to direct and guide airflow laterally (e.g., side-to-side) from the first inlet port **202*p*-1** to below the cover **202** to the PCB **210** (see, e.g., FIG. **3**D). According to an embodiment, cover **202** further comprises at least one second inlet port **202*p*-2** through a second lateral sidewall **202*s*-2** opposing the first lateral sidewall, and a second cooling duct **202*d*-2** at least in part coincident with the second inlet port **202*p*-2**. The second cooling duct **202*d*-2** is configured to cover an electronic component **210-1** (FIG. **5**C) extending from the PCB **210** and to direct and guide airflow laterally from the second inlet port **202*p*-2** around the electronic component **210-1** to below the cover **202** to the PCB **210** (see, e.g., FIG. **3**C).

[0041] FIG. **3**A is a top perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, FIG. **3**B is a top perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, FIG. **3**C is a bottom perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, and FIG. **3**D is a bottom perspective view illustrating a top cover of SSD device of FIGS. **2**A-**2**B, all according to embodiments. Illustrated further here are the first inlet port **202*p*-1** (see, e.g., FIG. **3**B) through the first lateral sidewall **202*s*-1** and the coincident first cooling duct **202*d*-1** (see, e.g., FIG. **3**A) of cover **202**. As discussed, the first cooling duct **202*d*-1** is configured to direct airflow laterally from the first inlet port **202*p*-1** to below the cover **202** to the PCB **210** (see, e.g., FIG. **3**D), whereby the placement of the first cooling duct **202*d*-1** and first inlet port **202*p*-1** may vary from implementation to implementation based, for example, on PCB hot spot target(s) (for non-limiting examples, controller, NAND, and the like). Cooling duct **202*d*-1**, **202*d*-2** count, opening size, and placement may vary from implementation to implementation based, for non-limiting examples, on cooling performance goals and in view structural properties (e.g., shock, vibration, thermal cycle, etc.) and electromagnetic compatibility ("EMC") performance and the like. Furthermore, according to embodiments the airflow direction may be adjusted by complementary design and placement of PCB **210** components, as well as by complementary placement of thermal interface material ("TIM", e.g., which conducts heat between two or more mating surfaces) according to a detail design.

[0042] As discussed and according to an embodiment, the second cooling duct **202*d*-2** of the cover **202** is configured to cover an electronic component **210-1** (FIG. **5**C) extending from the PCB **210** and to direct airflow laterally from the second inlet port **202*p*-2** around the electronic component **210-1** to below the cover **202** to the PCB **210** (see, e.g., FIG. **3**C). For example, PCB **210** of storage device **200** may include an electronic capacitor (see, e.g., power loss capacitor **174** of FIG. **1**) that may be a relatively large electronic component that therefore extends from the main board of PCB **210**. Here, cooling duct **202*d*-2** may be placed wherever a relatively oversized extending PCB component may be positioned, and may be structurally and/or aerodynamically configured to guide airflow around such a component accordingly.

[0043] FIG. **4**A is a perspective view illustrating a bottom base of SSD device of FIGS. **2**A-**2**B, and FIG. **4**B is a perspective view illustrating a bottom base of SSD device of FIGS. **2**A-**2**B, both according to embodiments. Shown here is the base **204** comprising a first inlet port **204*p*-1** through a first lateral sidewall **204*s*-1** of the base **204** and which is positioned to be substantially coincident with the first inlet port of the cover **202*p*-1**. According to an embodiment, the base **204** further comprises at least one second inlet port **204*p*-2** through a second lateral sidewall **204*s*-2** of the base **204** and which is positioned to be substantially coincident with the second inlet port **202*p*-1** of the cover **202**. According to an embodiment, one or more inlet port **204*p*-1**, **204*p*-2** of base **204** may be augmented with a chamfer feature at the hole edge to increase air velocity.

[0044] FIG. **4**A further illustrates a first specification-restricted area **204*s*-2-1** of the second lateral sidewall **204*s*-2** of the base **204** and a second specification-restricted area **204*s*-2-2** of the second lateral sidewall **204*s*-2** of the base **204**, according to which the at least one second inlet port **204*p*-2** of the base **204** is positioned between to avoid such restricted areas. Similarly, FIG. **4**B further illustrates a first specification-restricted area **204*s*-1-1** of the first lateral sidewall **204*s*-1** of the base **204** and a second specification-restricted area **204*s*-1-2** of the first lateral sidewall **204*s*-1** of the base **204**, according to which the first inlet port **204*p*-1** of the base **204** is positioned between to avoid those restricted areas. For example, the E3.S 2T (short) and E3.L 2T (long) (both having 16.8 millimeter max thickness form factor) specifications specify that each of the first specification-restricted areas **204*s*-1-1**, **204*s*-2-1** of their respective sidewall **204*s*-1**, **204*s*-2** are reserved as electrical grounding surface areas. Similarly, the E3.S 2T and E3.L 2T specifications specify that each of the second specification-restricted areas **204*s*-1-2**, **204*s*-2-2** of their respective sidewall **204*s*-1**, **204*s*-2** are reserved as riding surface areas for positioning of device carriers/installation structures associated with a given storage device **200**.

[0045] FIG. **5**A is a perspective view illustrating an SSD device assembly defining cross-sections, FIG. **5**B is a first cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, FIG. **5**C is a second cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, FIG. **5**D is a third cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, and FIG. **5**E is a fourth cross-sectional perspective view illustrating the SSD device assembly of FIG. **5**A, all according to embodiments. Collectively, FIGS. **5**A-**5**E further illustrate the foregoing cooling duct/inlet features.

[0046] Thus, FIG. **5**B illustrates a first cross-section **5**B-**5**B of storage device **200**, sectioning through a second inlet port **204*p*-2** of the base **204**, and a second inlet port **202*p*-2** and corresponding second cooling duct **202*d*-2** of the cover **202** of storage device **200**, including some of the airflow-directing structural contour (e.g., laterally and longitudinally) of the inside of second cooling duct **202*d*-2**. FIG. **5**C illustrates a second cross-section **5**C-**5**C of storage device **200**, sectioning through the second lateral sidewall **204*s*-2** of the base **204**, and the second inlet port **202*p*-2** and corresponding second cooling duct **202*d*-2** of the cover **202**, including some of the airflow-directing structural contour of the inside of second cooling duct **202*d*-2** around the electronic component **210-1** of PCB **210**. FIG. **5**D illustrates a third cross-section **5**D-**5**D of storage device **200**, again sectioning through a second inlet port **204*p*-2** of the base **204**, and the second inlet port **202*p*-2** and corresponding second cooling duct **202*d*-2** of the cover **202**, including some of the airflow-directing structural contour (primarily laterally) of the inside of second cooling duct **202*d*-2**, directing airflow to PCB **210** (electronic component **210-1** removed in this view). Finally, FIG. **5**E illustrates a fourth cross-section **5**E-**5**E of storage device **200**, sectioning through the first inlet port **204*p*-1** of the base **204** and the first inlet port **202*p*-1** and corresponding first cooling duct **202*d*-1** of the cover **202**, including some of the airflow-directing structural contour of the inside of second cooling duct **202*d*-1**, directing airflow to PCB **210**.

[0047] FIG. **6** is a perspective view illustrating an SSD device assembly with cooling ventilation features, according to an embodiment. An electronic storage device such as illustrated storage device **600** is configured to comprise one or more printed circuit board such as PCB **210** of FIGS. **5**B-**5**E (see also, e.g., the components of SSD **152** of FIG. **1**) within a device enclosure described hereafter. According to an embodiment, storage device **600** comprises a PCB including non-volatile memory. Similarly, and according to an embodiment, storage device **600** comprises a PCB including NAND (NOT AND) flash memory. Furthermore, and according to an embodiment, storage device **600** is a solid-state drive (SSD) storage device (see, e.g., SSD **152** of FIG. **1**).

[0048] Storage device **600** comprises an enclosure cover **602** (“cover **602**”) coupled to an enclosure base **604** (“base **604**”). According to an embodiment, cover **602** comprises a first row **603** of first ventilation slots **603*a*-603*n***, through a first lateral sidewall **602*s*-1** of the cover **602**, configured to direct airflow generally laterally over an outer side **6020** of the cover **602**. Likewise, according to an embodiment the cover **602** comprises second row **603** of second ventilation slots **603*a*-603*m***, through a second lateral sidewall **602*s*-2** of the cover **602** (see, e.g., FIGS. **7**A-**7**B). Similarly, the base **604** comprises a first row **605** of first ventilation slots **605*a*-605*n***, through a first lateral sidewall **604*s*-1** of the base **604** and substantially coincident with the first ventilation slots **603*a*-603*n*** of the cover **602**, configured to direct airflow generally laterally over the outer side **6020** of the cover **602**. Here also, according to an embodiment the base **604** comprises a second row **605** of second ventilation slots **605*a*-605*m***, through a second lateral sidewall **604*s*-2** of the base **604** (see, e.g., FIGS. **8**A-**8**B), and substantially coincident with the second ventilation slots **603*a*-603*m*** of the cover **602**. The utilization of such ventilation slots **603*a*-603*n***, **605*a*-605*n*** to direct airflow over the cover **602** is discussed in more detail elsewhere herein, such as in reference to FIGS. **12**A-**12**C.

[0049] FIG. **7**A is a perspective view illustrating a top cover of SSD device of FIG. **6**, and FIG. **7**B is a perspective view illustrating the top cover of SSD device of FIG. **6**, both according to embodiments. As discussed, cover **602** comprises a row **603** of ventilation slots through one or both of the first and second lateral sidewall **602*s*-1**, **602*s*-2**, which are configured to direct airflow over the outer side **6020** of the cover **602**. In FIGS. **7**A-**7**B, first lateral sidewall **602*s*-1** of cover **602** is depicted with a row **603** of ventilation slots **603*a*-603*n***, where n represents an arbitrary number of slots that may vary from implementation to implementation. Furthermore, second lateral sidewall **602***s***-2** of cover **602** is depicted with a row **603** of ventilation slots **603***a***-603***m*, where m represents an arbitrary number of slots that may vary from implementation to implementation. With implementations in which a second cooling duct is present, such as second cooling duct **202***d***-2** (see, e.g., FIGS. **2**A-**3**D), n and m are likely unequal due to the presence of the second cooling duct **202***d***-2**.

[0050] FIG. **8**A is a perspective view illustrating a bottom base of SSD device of FIG. **6**, and FIG. **8**B is a perspective view illustrating the bottom base of SSD device of FIG. **6**, all according to embodiments. As discussed, base **604** comprises a row **605** of ventilation slots through one or both of the first and second lateral sidewall **604***s***-1**, **604***s***-2**, which are configured to direct airflow over the outer side **6020** (FIGS. **7**A-**7**B) of the cover **602**. In FIGS. **8**A-**8**B, first lateral sidewall **604***s***-1** of base **604** is depicted with a row **605** of ventilation slots **605***a***-605***n*, where n represents an arbitrary number of slots that may vary from implementation to implementation. Furthermore, second lateral sidewall **605***s***-2** of base **604** is depicted with a row **605** of ventilation slots **605***a***-605***m*, where m represents an arbitrary number of slots that may vary from implementation to implementation. As discussed and according to an embodiment, the row **605** of ventilation slots **605***a***-605***n* through the first lateral sidewall **604***s***-1** of the base **604** are positioned between a first specification-restricted area **604***s***-1-1** and a second specification-restricted area **604***s***-1-2** of the of the first lateral sidewall **604***s***-1** of the base **604**. Likewise, the row **605** of ventilation slots **605***a***-605***m* through the second lateral sidewall **604***s***-2** of the base **604** are positioned between a first specification-restricted area **604***s***-2-1** and a second specification-restricted area **604***s***-2-2** of the of the second lateral sidewall **604***s***-2** of the base **604**.

[0051] FIG. **9**A is a perspective view illustrating a first end of an SSD device assembly with cooling ventilation features, and FIG. **9**B is a perspective view illustrating a second end of an SSD device assembly with cooling ventilation features, both according to embodiments. Storage device **900** comprises an enclosure cover **902** ("cover **902**") coupled to an enclosure base **904** ("base **904**"). According to an embodiment, the cover **902** comprises a first series of tooth structures **902***t***-1** separated by slits **902***s***-1** through a first end wall **902***e***-1** of the cover **902** (e.g., the host connector end), and the base **904** comprises a first series of tooth structures **904***t***-1** separated by slits **904***s***-1** through a first end wall **904***e***-1** of the base **904** (e.g., the host connector end). Each tooth structure of the first series of tooth structures **904***t***-1** of the base **904** mechanically interfaces with a corresponding tooth structure of the first series of tooth structures **902***t***-1** of the cover **902**. Furthermore and according to an embodiment, the cover **902** further comprises a second series of tooth structures **902***t***-2** separated by slits **902***s***-2** through a second end wall **902***e***-2** of the cover **902** (e.g., the LED (light-emitting diode) end) opposing the first end wall **902***e***-1** of the cover **902**, and the base **904** further comprises a second series of tooth structures **904***t***-2** separated by slits **904***s***-2** through a second end wall **904***e***-2** of the base **904** (e.g., the LED end), opposing the first end wall **904***e***-1** of the base **904**. Each tooth structure of the second series of tooth structures **904***t***-2** of the base **904** mechanically interfaces with a corresponding tooth structure of the second series of tooth structures **902***t***-2** of the cover **902**.

[0052] According to an embodiment, the slits **902***s***-1**, **902***s***-2** through the first end wall **902***e***-1** and the second end wall **902***e***-2** of the cover **902** are approximately 2 millimeters wide laterally, and the slits **904***s***-1**, **904***s***-2** through the first end wall **904***e***-1** and the second end wall **904***e***-2** of the base **904** are similarly approximately 2 millimeters wide laterally, i.e., sufficiently small enough for mitigating electrostatic discharge (ESD), whereby electrical discharge energy can flow into big openings and shock the electronic components, while still enabling sufficient cooling airflow into and through the storage device **900**. ESD, sometimes referred to as "static electricity", is a momentary flow of electrical current between two differently-charged objects when brought into contact or even when brought close together. It is well-known that ESD can cause damage to and even failure of solid-state electronics components such as integrated circuits, which can suffer permanent damage when subjected to high voltages. Thus, sensitive components need to be protected from ESD.

[0053] FIG. **10**A is a perspective view illustrating the first end of a top cover of SSD device assembly of FIGS. **9**A-**9**B, and FIG. **10**B is a perspective view illustrating the second end of the top cover of SSD device assembly of FIGS. **9**A-**9**B, both according to embodiments. As discussed and as depicted in FIG. **10**A, according to an embodiment cover **902** comprises a first series of tooth structures **902***t***-1** separated by slits **902***s***-1**, at one first end wall **902***e***-1** of the cover **902**. Similarly and as depicted in FIG. **10**B, according to an embodiment cover **902** further comprises a second series of tooth structures **902***t***-2** separated by slits **902***s***-2**, at one second end wall **902***e***-2** of the cover **902**. According to an embodiment, each tooth structure of the first and second series of tooth structures **902***t***-1**, **902***t***-2** of the cover **902** comprises a step structure, as depicted in FIGS. **10**A-**10**B, configured for mechanically interfacing with the corresponding tooth structure of the first and second series of tooth structures **904***t***-1**, **904***t***-2** (FIGS. **9**A-**9**B, **11**A-**11**B) of the base **904**.

[0054] FIG. **11**A is a perspective view illustrating the first end of a bottom base of SSD device assembly of FIGS. **9**A-**9**B, and FIG. **11**B is a perspective view illustrating the second end of the bottom base of SSD device assembly of FIGS. **9**A-**9**B, both according to embodiments. As discussed and as depicted in FIG. **11**A, according to an embodiment base **904** comprises a first series of tooth structures **904***t***-1** separated by slits **904***s***-1**, at one first end wall **904***e***-1** of the base **904**. Similarly and as depicted in FIG. **11**B, according to an embodiment base **904** further comprises a second series of tooth structures **904***t***-2** separated by slits **904***s***-2**, at one second end wall **904***e***-2** of the base **904**. According to an embodiment, each tooth structure of the first and second series of tooth structures **904***t***-1**, **904***t***-2** of the base **904** comprises a step structure, as depicted in FIGS. **11**A-**11**B, configured for mechanically interfacing with the corresponding tooth structure of the first and second series of tooth structures **902***t***-1**, **902***t***-2** (FIGS. **9**A-**9**B, **10**A-**10**B) of the cover **902**.

[0055] With known prior approaches to SSDs, small holes are implemented through the enclosure end walls for air ventilation purposes to meet thermal performance requirements. The manufacturing of such small holes required machining (e.g., computer numerical control, or “CNC”, machining), requiring a significant material cost increase. By contrast, use of the tooth-slit structures **902***t***-1** with **902***s***-1**, **902***t***-2** with **902***s***-2** for the cover **902** and the tooth-slit structures **904***t***-1** with **904***s***-1**, **904***t***-2** with **904***s***-2** for the base **904**, enables manufacturing of each of the cover **902** and the base **904** by a casting (e.g., diecasting) process absent (or without requiring) machining, e.g., the machining of tiny ventilation holes. Thus, less costly cover **902** and base **904** structures may be manufactured.

[0056] FIG. **12**A is an end perspective view illustrating a solid-state storage device, FIG. **12**B is a side perspective view illustrating the solid-state storage device of FIG. **12**A, and FIG. **12**C is a cross-sectional perspective view illustrating the solid-state storage device of FIG. **12**A, all according to embodiments. Storage device **1200** illustrates a combination of the cooling features described in more detail elsewhere herein. For example, storage device **1200** is depicted as comprising a cover **1202** over a base **1204** to which a PCB (see, e.g., PCB **210** of FIGS. **5**B-**5**E) is mounted or in which a PCB is otherwise housed. A storage device (e.g., SSD) such as storage device **1200** may be implemented with the first inlet duct **202***d***-1**, and associated first inlet port **202***p***-1** of cover **202** and first inlet port **204***p***-1** of base **204** (see, also e.g., FIGS. **2**A-**5**E), and/or the second inlet duct **202***d***-2** such as over a PCB component **210-1** (see also, e.g., FIG. **5**C), and associated second inlet port **202***p***-2** of cover **202** and second inlet port **204***p***-2** of base **204** (see also, e.g., FIGS. **2**A-**5**E).

[0057] Furthermore, a storage device such as storage device **1200** may be implemented with the first and/or second row **603** of ventilation slots **603***a***-603***n*, **603***a***-603***m* of cover **602** (see, also e.g., FIGS. **6-7**B), and/or the first and/or second row **605** of ventilation slots **605***a***-605***n*, **605***a***-605***m* of base **604** (see, also e.g., FIGS. **6**, **8**A-**8**B), positioned between first specification-restricted area

604*s***-1-1** and second specification-restricted area **604***s***-1-2** on one side and/or between first specification-restricted area **604***s***-2-1** and second specification-restricted area **604***s***-2-2** on the other side, and which are configured to direct airflow generally laterally over the outer side **6020** (see, e.g., FIGS. **6-7**B) of the cover **602**, **1202**. According to an embodiment, storage device **1200** comprises an outer side of cover **1202** which further comprises a grouping or array of heatsink structures **1220** extending from a main body of cover **1202**. Thus, directing the airflow across the outer side **6020** of the cover **1202** includes directing airflow through the ventilation slots **603***a***-603***n* and/or **603***a***-603***m* of cover **602** and the ventilation slots **605***a***-605***n* and/or **605***a***-605***m* of base **604** across the array of heatsink structures **1220** thereby enhancing or augmenting the storage device **1200** and corresponding PCB **210** cooling process.

[0058] Still further, a storage device such as storage device **1200** may be implemented with the first and/or second tooth structures **902***t***-1** with slits **902***s***-1**, tooth structures **902***t***-2** with slits **902***s***-2** of the cover **1202** (see also, e.g., FIGS. **9**A-**10**B), and the first and/or second tooth structures **904***t***-1** with slits **904***s***-1**, tooth structures **904***t***-2** with slits **904***s***-2** of the base **1204** (see also, e.g., FIGS. **9**A, **11**A-**11**B), configured to enable cost effective end-to-end airflow through storage device **1200** while mitigating ESD risk.

Method of Assembling a Data Storage Device

[0059] FIG. **13** is a flow diagram illustrating a method of assembling a data storage device, according to an embodiment. For example, the method of FIG. **13** may be implemented to assemble a storage device **200** as exemplified in the illustrations and descriptions corresponding to FIGS. **2**A-**2**B, a storage device **600** as exemplified in the illustrations and descriptions corresponding to FIG. **6**, a storage device **900** as exemplified in the illustrations and descriptions corresponding to FIGS. **9**A-**9**B, and a storage device **1200** as exemplified in the illustrations and descriptions corresponding to FIGS. **12**A-**12**C.

[0060] At block **1302**, couple a printed circuit board (PCB) to an enclosure base comprising (i) a first inlet port through a first lateral sidewall of the base and positioned between a first specification-restricted area of the first lateral sidewall of the base and a second specification-restricted area of the first lateral sidewall of the base, and (ii) at least one second inlet port through a second lateral sidewall of the base and positioned between a first specification-restricted area of the second lateral sidewall of the base and a second specification-restricted area of the second lateral sidewall of the base. For example, PCB **210** (FIGS. **5**B-**5**E) is coupled to an enclosure base **204** (FIGS. **2**A-**2**B, **4**A-**4**B, **5**B-**5**E), **604** (FIGS. **6**, **8**A-**8**B), **904** (FIGS. **9**A-**9**B, **11**A-**11**B), **1204** (FIGS. **12**A-**12**B) comprising (i) a first inlet port **204***p***-1** (FIGS. **2**A-**2**B, **4**A-**4**B, **5**B-**5**E) through a first lateral sidewall **204***s***-1** (FIGS. **2**A-**2**B, **4**A-**4**B, **5**B-**5**E) of the base **204**, **604**, **904**, **1204** and positioned between a first specification-restricted area **604***s***-1-1** (FIGS. **8**A-**8**B) of the first lateral sidewall **604***s***-1** (FIGS. **8**A-**8**B) of the base **604** and a second specification-restricted area **604***s***-1-2** (FIGS. **8**A-**8**B) of the first lateral sidewall **604***s***-1** of the base **604**, and (ii) at least one second inlet port **204***p***-2** (FIGS. **2**A-**2**B, **4**A-**4**B, **5**B-**5**E) through a second lateral sidewall **204***s***-2** (FIGS. **2**A-**2**B, **4**A-**4**B, **5**B-**5**E) of the base **204**, **604**, **904**, **1204** and positioned between a first specification-restricted area **604***s***-2-1** (FIGS. **8**A-**8**B) of the second lateral sidewall **604***s***-2** (FIGS. **8**A-**8**B) of the base **204**, **604**, **904**, **1204** and a second specification-restricted area **604***s***-2-2** (FIGS. **8**A-**8**B) of the second lateral sidewall **604***s***-2** of the base **204**, **604**, **904**, **1204**.

[0061] At block **1304**, couple to the base a cover covering the PCB, the cover comprising (i) a first inlet port through a first lateral sidewall of the cover and at least in part coincident with the first inlet port of the base, (ii) a first cooling duct at least in part coincident with the first inlet port of the cover, the first cooling duct configured to direct airflow laterally from the first inlet port of the cover to below the cover to the PCB, (iii) at least one second inlet port through a second lateral sidewall of the cover opposing the first lateral sidewall and at least in part coincident with the second inlet port of the base, and (iv) a second cooling duct at least in part coincident with the second inlet port of the cover, the second cooling duct configured to cover an electronic component extending from the PCB and to direct airflow laterally from the second inlet ports around the electronic component to below the cover to the PCB. For example, cover **202** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E), **604** (FIGS. **6**, **7**A-**7**B), **904** (FIGS. **9**A-**9**B, **10**A-**10**B), **1204** (FIGS. **12**A-**12**B) is coupled to base **204**, **604**, **904**, **1204** over the PCB **210**, the cover **202**, **602**, **902**, **1202** comprising (i) a first inlet port **202***p***-1** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) through a first lateral sidewall **202***s***-1** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) of the cover **202**, **602**, **902**, **1202** and at least in part coincident with the first inlet port **204***p***-1** of the base **204**, **604**, **904**, **1204**, (ii) a first cooling duct **202***d***-1** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) at least in part coincident with the first inlet port **202***p***-1** of the cover **202**, **602**, **902**, **1202**, the first cooling duct **202***d***-1** configured to direct airflow laterally from the first inlet port **202***p***-1** of the cover **202**, **602**, **902**, **1202** to below the cover to the PCB **210**, (iii) at least one second inlet port **202***p***-2** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) through a second lateral sidewall **202***s***-2** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) of the cover **202**, **602**, **902**, **1202** opposing the first lateral sidewall **202***s***-1** and at least in part coincident with the second inlet port **204***p***-2** of the base **204**, **604**, **904**, **1204**, and (iv) a second cooling duct **202***d***-2** (FIGS. **2**A-**2**B, **3**A-**3**D, **5**B-**5**E) at least in part coincident with the second inlet port **202***p***-2** of the cover **202**, **602**, **902**, **1202**, the second cooling duct **202***d***-2** configured to cover an electronic component **210-1** (FIG. **5**C) extending from the PCB **210** and to direct airflow laterally from the second inlet port **202***p***-2** around the electronic component **210-1** to below the cover **202**, **602**, **902**, **1202** to the PCB **210**.

[0062] As described throughout herein, for a storage device such as an SSD, implementation of one or more cooling features described herein enables cost-effective (e.g., avoiding machining operations) enhanced airflow, ventilation, and cooling (e.g., using inlet ports and ducts and/or rows of ventilation slots for enabling lateral airflow to a PCB and/or over a cover/heatsinks) of such a device, within constraints that may be imposed by standard specifications to which the device may correspond (e.g., the grounding and riding surfaces required of the E3 family of specifications for SSDs), and while mitigating ESD risks associated with openings through ends (e.g., LED end, host connector end) of such a device.

Physical Description of an Illustrative Operating Context

[0063] Embodiments may be used in the context of electronic devices including digital data storage devices (DSDs), such as a solid-state drives (SSDs). Thus, FIG. **1** is a block diagram illustrating a generic SSD architecture **150**, for an example operating context of an electronic device with which embodiments of the invention may be implemented. The generic SSD architecture **150** depicts an SSD **152** communicatively coupled with a host **154** through a primary communication interface **156**. SSD implementations are not limited to a configuration as depicted in FIG. **1**, as embodiments may be implemented with SSD configurations other than that illustrated in FIG. **1** and/or with electronic devices other than SSDs.

[0064] Host **154** broadly represents any type of computing hardware, software, or firmware (or any combination of the foregoing) that makes, among others, data I/O requests or calls to one or more memory device. For example, host **154** may be an operating system executing on a computer, a tablet, a mobile phone, or generally any type of computing device that contains or interacts with storage memory. The primary interface **156** coupling host **154** to SSD **152** may be, for example, a storage system's internal bus or a communication cable or a wireless communication link, or the like.

[0065] The example SSD **152** illustrated in FIG. **1** includes an interface **160**, a controller **162** (e.g., a controller having firmware logic therein), an addressing **164** function block, data buffer cache **166**, and one or more non-volatile memory (NVM) components **170***a*, **170***b*-**170***n*, where n represents an arbitrary number of NVM components that may vary from implementation to implementation.

[0066] Interface **160** is a point of interaction between components, namely SSD **152** and host **154** in this context, and is applicable at the level of both hardware and software. This enables a component to communicate with other components via an input/output (IO) system and an associated protocol. A hardware interface is typically described by the mechanical, electrical and logical signals at the interface and the protocol for sequencing them. Some non-limiting examples of common and standard interfaces include SCSI (Small Computer System Interface), SAS (Serial Attached SCSI), and SATA (Serial ATA).

[0067] An SSD **152** includes a controller **162**, which incorporates the electronics that bridge the non-volatile memory components (e.g., NAND flash) to the host, such as non-volatile memory **170***a*, **170***b*-**170***n* to host **154**. The controller is typically an embedded processor that executes firmware-level code and can be a significant factor in SSD performance.

[0068] Controller **162** interfaces with non-volatile memory **170***a*, **170***b*-**170***n* via an addressing **164** function block. The addressing **164** function operates, for example, to manage mappings between logical block addresses (LBAs) from the host **154** to a corresponding physical block address on the SSD **152**, namely, on the non-volatile memory **170***a*, **170***b*-**170***n* of SSD **152**. Because the non-volatile memory page and the host sectors are different sizes, an SSD has to build and maintain a data structure that enables it to translate between the host writing data to or reading data from a sector, and the physical non-volatile memory page on which that data is actually placed. This table structure or “mapping” may be built and maintained for a session in the SSD's volatile memory **172**, such as DRAM or some other local volatile memory component accessible to controller **162** and addressing **164**. Alternatively, the table structure may be maintained more persistently across sessions in the SSD's non-volatile memory such as non-volatile memory **170***a*, **170***b*-**170***n*.

[0069] Addressing **164** interacts with data buffer cache **166**, in addition to non-volatile memory **170***a*, **170***b*-**170***n*. Data buffer cache **166** of an SSD **152** typically uses DRAM as a cache, similar to the cache in hard disk drives. Data buffer cache **166** serves as a buffer or staging area for the transmission of data to and from the non-volatile memory components, as well as serves as a cache for speeding up future requests for the cached data. Data buffer cache **166** is typically implemented with volatile memory so the data stored therein is not permanently stored in the cache, i.e., the data is not persistent.

[0070] Finally, SSD **152** includes the one or more non-volatile memory **170***a*, **170***b*-**170***n* components. For a non-limiting example, the non-volatile memory components **170***a*, **170***b*-**170***n* may be implemented as flash memory (e.g., NAND or NOR flash), or other types of solid-state memory available now or in the future. The non-volatile memory **170***a*, **170***b*-**170***n* components are the actual memory electronic components on which data is persistently stored. The non-volatile memory **170***a*, **170***b*-**170***n* components of SSD **152** can be considered the analogue to the hard disks in hard-disk drive (HDD) storage devices.

[0071] Furthermore, references herein to a data storage device may encompass a multi-medium storage device (or “multi-medium device”, which may at times be referred to as a “multi-tier device” or “hybrid drive”). A multi-medium storage device refers generally to a storage device having functionality of both a traditional HDD (see, e.g., HDD **100**) combined with an SSD (see, e.g., SSD **150**) using non-volatile memory, such as flash or other solid-state (e.g., integrated circuits) memory, which is electrically erasable and programmable. As operation, management and control of the different types of storage media typically differ, the solid-state portion of a hybrid drive may include its own corresponding controller functionality, which may be integrated into a single controller along with the HDD functionality. A multi-medium storage device may be architected and configured to operate and to utilize the solid-state portion in a number of ways, such as, for non-limiting examples, by using the solid-state memory as cache memory, for storing frequently-accessed data, for storing I/O intensive data, for storing metadata corresponding to payload data (e.g., for assisting with decoding the payload data), and the like. Further, a multi-medium storage device may be architected and configured essentially as two storage devices in a single enclosure, i.e., a traditional HDD and an SSD, with either one or multiple interfaces for host connection.

EXTENSIONS AND ALTERNATIVES

[0072] In the foregoing description, embodiments of the invention have been described with reference to numerous specific details that may vary from implementation to implementation. Therefore, various modifications and changes may be made thereto without departing from the broader spirit and scope of the embodiments. Thus, the sole and exclusive indicator of what is the invention, and is intended by the applicants to be the invention, is the set of claims that issue from this application, in the specific form in which such claims issue, including any subsequent correction. Any definitions expressly set forth herein for terms contained in such claims shall govern the meaning of such terms as used in the claims. Hence, no limitation, element, property, feature, advantage or attribute that is not expressly recited in a claim should limit the scope of such claim in any way. The specification and drawings are, accordingly, to be regarded in an illustrative rather than a restrictive sense.

[0073] In addition, in this description certain process steps may be set forth in a particular order, and alphabetic and alphanumeric labels may be used to identify certain steps. Unless specifically stated in the description, embodiments are not necessarily limited to any particular order of carrying out such steps. In particular, the labels are used merely for convenient identification of steps, and are not intended to specify or require a particular order of carrying out such steps.

Claims

1. An electronic storage device comprising: an enclosure base; a printed circuit board (PCB) coupled with the base; and an enclosure cover coupled with the base and covering the PCB, the cover comprising: a first inlet port through a first lateral sidewall of the cover, and a first cooling duct at least in part coincident with the first inlet port, the first cooling duct configured to direct airflow laterally from the first inlet port to below the cover to the PCB.

2. The electronic storage device of claim 1, wherein the first cooling duct is further configured to direct airflow from the first inlet port to a target hot spot of the PCB.

3. The electronic storage device of claim 1, wherein: the cover further comprises a row of ventilation slots, through the first lateral sidewall of the cover, configured to direct airflow over an outer side of the cover; and the base comprises a row of ventilation slots, through a first lateral sidewall of the base and substantially coincident with the ventilation slots of the cover, configured to direct airflow over the outer side of the cover.

4. The electronic storage device of claim 3, wherein the outer side of the cover comprises a plurality of heatsink structures extending from a main body of the cover.

5. The electronic storage device of claim 1, wherein the base comprises a first inlet port through a first lateral sidewall of the base and substantially coincident with the first inlet port of the cover.

6. The electronic storage device of claim 1, wherein: the cover further comprises: at least one second inlet port through a second lateral sidewall of the cover opposing the first lateral sidewall, and a second cooling duct at least in part coincident with the second inlet port, the second cooling duct configured to cover an electronic component extending from the PCB and to direct airflow laterally from the second inlet port around the electronic component to below the cover to the PCB.

7. The electronic storage device of claim 6, wherein the base comprises at least one second inlet port through a second lateral sidewall of the base and substantially coincident with the second inlet port of the cover.

8. The electronic storage device of claim 7, wherein: the at least one second inlet port of the base is positioned between a first specification-restricted area of the second lateral sidewall of the base and a second specification-restricted area of the second lateral sidewall of the base; and the base further comprises a first inlet port through a first lateral sidewall of the base and substantially coincident with the first inlet port of the cover and positioned between a first specification-restricted area of the first lateral sidewall of the base and a second specification-restricted area of the first lateral sidewall of the base.

9. The electronic storage device of claim 6, wherein the base comprises a row of ventilation slots, through the second lateral sidewall of the base, configured to direct airflow over an outer side of the cover and positioned between a first specification-restricted area of the second lateral sidewall of the base and a second specification-restricted area of the second lateral sidewall of the base.
10. The electronic storage device of claim 1, wherein: the base comprises a first series of tooth structures separated by slits through a first end wall of the base; the cover comprises a first series of tooth structures separated by slits through a first end wall of the cover; and each tooth structure of the first series of tooth structures of the base mechanically interfaces with a corresponding tooth structure of the first series of tooth structures of the cover.
11. The electronic storage device of claim 10, wherein: the base comprises a second series of tooth structures separated by slits through a second end wall of the base opposing the first end wall of the base; the cover comprises a second series of tooth structures separated by slits through a second end wall of the cover opposing the first end wall of the cover; and each tooth structure of the second series of tooth structures of the base mechanically interfaces with a corresponding tooth structure of the second series of tooth structures of the cover.
12. The electronic storage device of claim 11, wherein: each tooth structure of the first and second series of tooth structures of the base comprises a step structure configured for mechanically interfacing with the corresponding tooth structure of the first and second series of tooth structures of the cover; and each tooth structure of the first and second series of tooth structures of the cover comprises a step structure configured for mechanically interfacing with the corresponding tooth structure of the first and second series of tooth structures of the base.
13. The electronic storage device of claim 11, wherein: the slits through the first end wall and the second end wall of the base are approximately 2 millimeters wide laterally; the slits through the first end wall and the second end wall of the cover are approximately 2 millimeters wide laterally.
14. The electronic storage device of claim 10, wherein each of the base and the cover is formed by casting absent machining.
15. The electronic storage device of claim 1, wherein the electronic storage device is a solid-state drive (SSD) storage device.
16. A solid-state storage device comprising: a printed circuit board (PCB) comprising electronic means for non-volatile data storage; an enclosure cover coupled with an enclosure base and covering the PCB, the cover comprising: a first inlet port through a first lateral sidewall of the cover, a first cooling duct at least in part coincident with the first inlet port, the first cooling duct configured to direct airflow laterally from the first inlet port to below the cover to the PCB, at least one second inlet port through a second lateral sidewall of the cover opposing the first lateral sidewall, and a second cooling duct at least in part coincident with the second inlet port, the second cooling duct configured to cover an electronic component extending from the PCB and to direct airflow laterally from the second inlet port around the electronic component to below the cover to the PCB; and the enclosure base comprising: a first inlet port through a first lateral sidewall of the base and substantially coincident with the first inlet port of the cover and positioned between a first specification-restricted area of the first lateral sidewall of the base and a second specification-restricted area of the first lateral sidewall of the base, and at least one second inlet port through a second lateral sidewall of the base and substantially coincident with the second inlet port of the cover and positioned between a first specification-restricted area of the second lateral sidewall of the base and a second specification-restricted area of the second lateral sidewall of the base.
17. The solid-state storage device of claim 16, wherein: each of the first and second inlet ports of the cover is one of a row of ventilation slots, through the respective first and second lateral sidewall of the cover, configured to direct airflow over an outer side of the cover comprising extending heatsink structures; and each of the first and second inlet ports of the base is one of a row of ventilation slots, through the respective first and second lateral sidewall of the base, configured to direct airflow over the outer side of the cover.

18. The solid-state storage device of claim 16, wherein: the base is produced by diecasting without machining, and comprises: a first series of tooth structures separated by slits through a first end wall of the base, and a second series of tooth structures separated by slits through a second end wall of the base opposing the first end wall of the base; the cover is produced by diecasting without machining, and comprises: a first series of tooth structures separated by slits through a first end wall of the cover, and a second series of tooth structures separated by slits through a second end wall of the cover opposing the first end wall of the cover; each tooth structure of the first and second series of tooth structures of the base mechanically interfaces with a corresponding tooth structure of the respective first and second series of tooth structures of the cover.
19. A method of assembling a data storage device, the method comprising: coupling a printed circuit board (PCB) to an enclosure base comprising (i) a first inlet port through a first lateral sidewall of the base and positioned between a first specification-restricted area of the first lateral sidewall of the base and a second specification-restricted area of the first lateral sidewall of the base, and (ii) at least one second inlet port through a second lateral sidewall of the base and positioned between a first specification-restricted area of the second lateral sidewall of the base and a second specification-restricted area of the second lateral sidewall of the base; and coupling to the base a cover covering the PCB, the cover comprising (i) a first inlet port through a first lateral sidewall of the cover and at least in part coincident with the first inlet port of the base, (ii) a first cooling duct at least in part coincident with the first inlet port of the cover, the first cooling duct configured to direct airflow laterally from the first inlet port of the cover to below the cover to the PCB, (iii) at least one second inlet port through a second lateral sidewall of the cover opposing the first lateral sidewall and at least in part coincident with the second inlet port of the base, and (iv) a second cooling duct at least in part coincident with the second inlet port of the cover, the second cooling duct configured to cover an electronic component extending from the PCB and to direct airflow laterally from the second inlet ports around the electronic component to below the cover to the PCB.
20. The method of claim 19, further comprising: prior to coupling the PCB to the base, casting the base; and prior to coupling the cover to the base, casting the cover.