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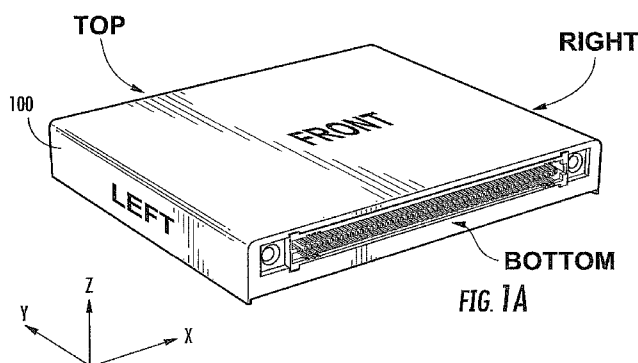
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(54) **Title:** PRINTED CIRCUIT BOARD MODULE ENCLOSURE AND APPARATUS USING SAME



(57) **Abstract:** A modular electronic component includes a circuit board having disposed thereon one or more electronic components and an enclosure for housing the circuit board. The enclosure comprises a thermally conductive shell having front and back surfaces being substantially parallel to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, left and right surfaces being substantially perpendicular to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, and top and bottom surfaces being substantially perpendicular to the left and right surfaces and substantially perpendicular to the top and bottom surfaces and being disposed on opposite sides of the circuit board from each other. A thermal shunt comprised of a thermally conductive material is disposed between the circuit board and the front surface of the enclosure and provides a thermally conductive path between at least some of the electronic components and the front surface of the enclosure, where the front surface of the enclosure conducts heat to at least one of the top, left, and right surfaces of the enclosure.



PRINTED CIRCUIT BOARD MODULE ENCLOSURE AND APPARATUS
USING SAME

DESCRIPTION

PRIORITY CLAIM

This application claims the benefit of U.S. Provisional Patent Application Serial No. 61/366,036, filed July 20, 2010, and U.S. Patent Application Serial
5 No. 12/882,161 filed September 14, 2010; the disclosures of each which are incorporated herein by reference in their entireties.

TECHNICAL FIELD

The subject matter described herein relates to modular, replaceable, and
10 reusable electronic components. More particularly, the subject matter described herein relates to a printed circuit board module enclosure and an apparatus using same.

BACKGROUND

15 The subject technology is a novel miniaturization of a packaging system known in the electronics industry as an air transport rack, or ATR. These rack standards were initially used for radio equipment deployed on WWII aircraft. Over the years, these rack standards were adapted for packaging of digital computer components, in a similar class of service. A full ATR box has the
20 following dimensions: width = 25.7cm, length = 49.6cm, height = 19.4cm.

Contemporary ATR boxes come in two lengths, long (49.6cm) and short (42.0cm), and come in a variety of widths, defined as a fraction of the width of a full ATR box. The widths include: 1 (25.7cm), $\frac{3}{4}$ (19.1cm), $\frac{1}{2}$ (12.4cm), $\frac{4}{8}$ (9.0cm), and $\frac{1}{4}$ (5.7cm). A typical small ATR form factor is the "one half, short
25 ATR", and is used to package 3U Euro-standard slot cards (least repairable units, LRUs).

As electrical components become increasingly miniaturized, however, the volume of even a quarter ATR box is needlessly large, and not only takes up valuable space within an aircraft but also contributes unnecessary weight.
30 Furthermore, miniaturization of electrical components is often accompanied by

an increase in power density and attendant thermal effects. Thus, simply packing more components into less space is an unworkable solution unless the problems of heat dissipation are also solved.

Conventional approaches to the problem of heat dissipation rely on air-cooling or water-cooling to dissipate the heat generated by densely packed electrical components. These approaches suffer significant weaknesses, however. Air cooling requires additional components, such as fans, filters, etc., that increase the cost and weight of the unit and which are additional components that may fail. The failure of a fan in particular can have a disastrous effect on the system operation. Water or liquid cooling is similarly expensive, heavy, and includes additional components that may fail.

Another conventional approach includes using heat spreaders to disperse heat away from the electronic components, usually to a heat sink. However, conventional systems that use heat spreaders suffer a significant weakness, as well: the heat spreader is coupled to the heat sink via the relatively small contact area of circuit board edges, which fit into shallow grooves in the heat sink. One popular approach uses Wedge-Lock® retainers, which are mounted to the printed circuit boards and are then inserted into channels machined into the cold plates or heat exchangers. The Wedge-Lock® system incurs some mechanical overhead, because the locking adapter must be mounted to the PCB and also because the system requires machined channels into which the locking adapters are inserted. As modules are scaled to smaller dimensions, this overhead becomes a larger and larger percentage of the total hardware. In addition, the contact surface through which heat may be transferred from the PCB to the cold-plate is limited to the width of the locking adapter portion, which limits the amount of heat conventional systems can dissipate. Because of the relatively small surface area provided for heat transfer, Wedge-Lock® systems have very high flux density. Moreover, as overall chassis volume is reduced, the Wedge-Lock® scheme does not scale at the same rate, thus occupying a relatively larger overhead, relative to the net available payload. In short, Wedge-Lock® systems are cumbersome, take up space, and are a potential point of failure.

Accordingly, in light of these disadvantages associated with conventional ATR boxes, there exists a need for a compact ATR form factor that includes enhanced thermal management capability. Specifically, there exists a need for a printed circuit board module enclosure and apparatus using same.

5

SUMMARY

According to one aspect, a modular electronic component includes a circuit board having disposed thereon one or more electronic components and an enclosure for housing the circuit board. The enclosure comprises a thermally conductive shell having front and back surfaces being substantially parallel to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, left and right surfaces being substantially perpendicular to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, and top and bottom surfaces being substantially perpendicular to the left and right surfaces and substantially perpendicular to the top and bottom surfaces and being disposed on opposite sides of the circuit board from each other. A thermal shunt comprised of a thermally conductive material is disposed between the circuit board and the front surface of the enclosure and provides a thermally conductive path between at least some of the electronic components and the front surface of the enclosure, where the front surface of the enclosure conducts heat to at least one of the top, left, and right surfaces of the enclosure.

According to another aspect, the subject matter described herein includes a modular electronic component system. The system includes a chassis for housing one or more modules for housing circuit boards, each module comprising a thermally conductive enclosure having front, back, left, right, and top surfaces and a circuit board disposed within the enclosure, where the plane of the circuit board is substantially parallel with the plane of the front and back surfaces and where the front surface of the module provides a path to conduct heat from the circuit board to the top, left, and right surfaces of the module. A backplane disposed along the bottom of the chassis provides one or more electrical connections to the modules. The backplane includes upward-facing electrical connectors for connecting to downward-facing

electrical connectors disposed along the bottom surface of the modules, which are inserted downward into the chassis. The system includes a heat dissipation means being in physical contact with and for conducting heat away from at least one of the top, left, and right surfaces of the modules.

5

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the subject matter described herein will now be explained with reference to the accompanying drawings, wherein like reference numerals represent like parts, of which:

10 Figures 1A, 1B, and 1C illustrate various views of an exemplary modular electronic component ("module") according to an embodiment of the subject matter described herein;

 Figures 2A, 2B, and 2C illustrate various views of an exemplary modular electronic component according to another embodiment of the subject matter
15 described herein;

 Figure 3 is an isometric view of an exemplary stand-alone modular electronic component according to another embodiment of the subject matter described herein;

20 Figures 4A, 4B, and 4C illustrate top, cross sectional views of exemplary modular electronic components according to embodiments of the subject matter described herein;

 Figures 4D and 4E illustrate the paths of heat conduction through an exemplary modular electronic component according to an embodiment of the subject matter described herein, including a top, cross sectional view and an
25 isometric view of a module;

 Figure 5A is an isometric view of a modularly pluggable electronic component system according to an embodiment of the subject matter described herein;

30 Figure 5B is an isometric view of the modularly pluggable electronic component system illustrated in Figure 5A, with finned heat sinks attached;

 Figure 5C is a top view of the modularly pluggable electronic component system illustrated in Figure 5B, with the top heat sink removed;

Figure 6A is a elevation cross sectional view of an exemplary modular electronic component as illustrated in Figure 1 installed in a modularly pluggable electronic component system as illustrated in Figure 4A according to an embodiment of the subject matter described herein;

5 Figure 6B illustrates a backplane with module connectors of a modularly pluggable electronic component system according to an embodiment of the subject matter described herein; and

 Figure 7 is a backplane module interconnect diagram of a modularly pluggable electronic component system according to an embodiment of the
10 subject matter described herein.

DETAILED DESCRIPTION

In accordance with the subject matter disclosed herein, a printed circuit board module enclosure having a small form factor and having enhanced
15 thermal management capabilities are provided, as well as an apparatus using same. The small form factor printed circuit board module and apparatus may be used to provide a small form factor air transport rack, herein referred to as a “nano air transport rack”, abbreviated as “nano-ATR”. A modularly pluggable electronic component system that uses the nano-ATR modules is also
20 presented.

Reference will now be made in detail to exemplary embodiments of the subject matter described herein, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. In one
25 embodiment, a nano-ATR module has dimensions of 1.25cm x 7.5cm x 8.9cm. Table 1, below, shows a comparison of ATR box sizes.

Table 1 – A comparison of ATR box sizes (cm)

ATR SIZE		Width	Length	Height
ATR	1 Long	25.7	49.6	19.4
ATR	1 Short	25.7	31.8	19.4
ATR	3/4 Short	19.1	31.8	19.4
ATR	1/2 Short	12.4	31.8	19.4
ATR	3/8 Short	9.0	31.8	19.4
ATR	1/4 Short	5.7	31.8	19.4
ATR	Dwarf	5.7	31.8	8.6
<i>nano-ATR chassis</i>		9.0	9.5	9.0
<i>nano-ATR module</i>		1.9	8.9	7.5

For more accurate comparison, the sizes listed in Table 1 are for boxes without heat sinks, fins, cold plates, and the like, which vary in size according to the needs of a particular installation.

As shown in Table 1, above, the smallest standard ATR box size is the dwarf ATR box, having dimensions in centimeters of (5.7 x 31.8 x 8.6) and a volume of 1558.8 cubic centimeters. In contrast, a nano-ATR form factor module according to one embodiment of the subject matter described herein has dimensions in centimeters of (1.9 x 8.9 x 7.5), and a chassis according to one embodiment has dimensions in centimeters of (9.0 x 9.5 x 9.0) and a volume of 769.5 cubic centimeters – less than half the volume of the smallest standard ATR box, the dwarf ATR box. Modules of two slot pitches, 12.5mm and 19mm are described. Thus, the packaging system described is significantly more compact than the earlier "ATR" standard systems.

Figures 1A, 1B, and 1C illustrate an exemplary modular electronic component ("module") according to an embodiment of the subject matter described herein. Figure 1A is an isometric view of a module **100** showing a backplane connector on the bottom surface of the module. Figure 1B is an isometric view of module **100** with a portion of the outer shell removed to reveal a circuit board **102** and backplane connector **104** contained within. Figure 1C is a plan view of circuit board **102** and backplane connector **104**. In one embodiment, module **100** is an enclosure comprised of a thermally conductive

shell, such as metal, composite, or other thermally conducting material. In Figure 1A, module **100** is shown with its front, top, bottom, left, and right surfaces identified. The back surface is not shown, but is opposite to the front surface. In one embodiment, backplane connector **104** is attached to circuit board **102** such that when circuit board **102** is attached or mounted within module **100**, the plane of circuit board **102** is substantially parallel to the front and back surfaces of module **100** and connector **104** is located at the bottom surface of module **100**. In one embodiment, the X and Y dimensions of circuit board **102** are 84mm and 70mm, respectively, and module **100** has X and Y dimensions of 89mm and 75mm, respectively. In the embodiment illustrated in Figure 1A, module **100** has a Z dimension of 12.5mm.

Figures 2A, 2B, and 2C illustrate an exemplary modular electronic component according to another embodiment of the subject matter described herein. Figure 2A is an isometric view of a module **200** showing a backplane connector on the bottom surface of the module. Figure 2B is an isometric view of module **200** with a portion of the outer shell removed to reveal a first circuit board **202**, which may also be referred to as carrier board **202**, and backplane connector **204** contained within. Module **200** also includes a second circuit board **206**, which may also be referred to as mezzanine card **206**, that connects to first circuit board **202** via a second connector **208**, which may also be referred to as mezzanine connector **208**. The first and second circuit boards may be respectively referred to as a mother and daughter card pair, or a carrier and mezzanine card pair, etc. Figure 2C is a plan view of carrier board **202** with its backplane connector **204** and mezzanine connector **208** and of mezzanine card **206**.

In one embodiment, module **200** is comprised of a thermally conductive shell, such as metal, composite, or other thermally conducting material. In one embodiment, the dimensions of carrier board **202** are 84mm x 70mm, the dimensions of mezzanine card **206** are 84mm x 55mm, and the dimensions of module enclosure **200** are 89mm x 75mm x 19mm. In one embodiment, mezzanine card **206** complies with the nano-ETX express standard.

Figure 3 is an isometric view of an exemplary modular electronic component according to another embodiment of the subject matter described

herein. Stand-alone module **300** encloses one or more circuit boards and uses the thermally conducting shell and internal skyline structure to provide a large surface area, e.g., the front, back, left, right, top and bottom surfaces of the shell by which heat may be dissipated. Stand-alone module **300** includes a
5 connector **302** disposed within the bottom of the module for providing an electrical connection to the circuit board(s) enclosed within. In one embodiment, stand-alone module **300** may be self-sufficient, i.e., not requiring external support. For example, stand-alone module **300** may contain its own internal power source. In one embodiment, stand-alone module **300** may
10 contain an internal power supply, such as batteries, in which case stand-alone module **300** does not require an external power source. Stand-alone module **300** may include a power converter for converting power that is supplied from internal batteries, supplied from an external source via connector **302**, or both, into power suitable for use by the module components, including conversions
15 from AC to DC, conversions from DC to DC, changes in voltage or current levels, power conditioning, providing auxiliary or backup power, and the like. In one embodiment, stand-alone module **300** may be sealed. Pluggable modules **100** and **200** may also be sealed against air, water, contaminants, etc.

Figures 4A, 4B, and 4C illustrate top, cross sectional views of exemplary
20 modular electronic components according to embodiments of the subject matter described herein. In each of Figures 4A, 4B, and 4C, the top cross-sectional view of module **200** shows the thermally conductive shell **200**, a carrier board **202**, connector **204**, and mezzanine card **206**. The same principles of thermal transfer via a thermally conductive shell may be utilized by
25 other embodiments, such as modules **100** and **300**, as well.

In the embodiment illustrated in Figure 4A, mezzanine card **206** includes a component **400**, which may be surface mounted to mezzanine card **206**. For example, component **400** may be a ball grid array package or other form of chip carrier upon which is mounted an integrated circuit, which may be encased
30 in plastic or other material. The embodiment illustrated in Figure 4A, the chip carrier is shown as a rectangle filled with diagonal lines and the material encasing the integrated circuit is shown as a rectangle filled with a stipple pattern, but other types of components are contemplated also.

A thermally conductive material **402** provides a thermal interface between component **400** and a thermally conductive shunt (the “thermal shunt”) **404** that is attached to the inside front surface of module **200**. In one embodiment, thermal shunt **404** may be a rigid material, such as aluminum, and thermally conductive material **402** may be a compliant material, designed to guarantee contact between component **400** and thermal shunt **404**. For this reason, thermally conductive material **402** may be referred to as a “thermal gasket.” Module **200** may have more than one component, however.

In one embodiment, a thermally conductive heat spreader may be interposed between thermal shunt **404** and an inside surface of thermally conductive shell **200**, to provide additional volume of thermally conductive material through which heat may be transferred from thermal shunt **404** to shell **200**, and to provide additional thermal contact area to shell **200**. Such a heat spreader can help distribute the heat away from a concentrated heat source, such as component **400**, across and through the entire surface or surfaces of thermally conductive shell **200**, increasing the efficiency of heat transfer way from circuit board **206**.

Figure 4B shows an alternative embodiment of module **200**, which includes multiple components **400A**, **400B**, and **400C**, each with its own thermal gasket **402A**, **402B**, and **402C**, respectively, and each with its own thermal shunt **404A**, **404B**, and **404C**, respectively.

Figure 4C shows yet another alternative embodiment of module **200**, which includes a variety of components (shown as black rectangles), each with its own thermal gasket but sharing a common thermal shunt **404D**. In the embodiment illustrated in Figure 4C, thermal shunt **404D** follows the contours of the underlying components, extending toward mezzanine board **206** when necessary to reach a component and extending away from mezzanine board **206** when it is necessary to avoid or clear other structures **406** that should not make contact with thermal shunt **404D**. The resulting contour of thermal shunt **404D** is reminiscent of a city skyline, and for this reason this type of thermal shunt (and thermal gasket) may be referred to as a “skyline structure”. The

thermal shunt and thermal gasket design may be used within single circuit board module **100** and stand-alone module **300** as well.

Figure 4D is another view of the module illustrated in Figure 4A, showing the path of heat conduction **408** from component **400** on mezzanine card **206**,
5 through thermal gasket **402** and thermal shunt **404** to the front surface of module **200**. Heat is dissipated from the front surface of module **200** to the left and right sides of module **200**, where a heat sink or other heat dissipation means will allow the heat to conduct away from module **200**.

Although Figures 4A through 4D illustrate embodiments having two
10 circuit boards, such as mother board **202** and daughter card **206**, the subject matter described herein is not so limited. The skyline structure **404** and thermal gasket **402** illustrated in Figure 4A, for example, may likewise be employed to provide a thermally conductive path away from components located on modules having only a single circuit board, such as circuit board **102**
15 within module **100**, as illustrated Figures 1A through 1C. The same principle may be likewise applied to modules having any number of circuit boards contained within.

Figure 4E is an isometric view of module **200**, showing that heat is dissipated not only to the left and right surfaces of module **200** but also to the
20 top surface. If the enclosure has a bottom surface, heat may be dissipated to the bottom surface as well. Heat sinks may be located on the left, right, and top surfaces of module **200**, and also may be located on the bottom surface or even the front or back surfaces as well. By using a thermally conducting shell in combination with the skyline structure, a substantial amount of surface area
25 can either dissipate heat directly or can provide contact area for a heat sink, cold plate, or other cooling structure.

Figure 5A, 5B, and 5C illustrate views of a modularly pluggable electronic component system according to an embodiment of the subject matter described herein.

30 Figure 5A illustrates an isometric view of a chassis **500** for holding pluggable modules **502**. In the embodiment illustrated in Figure 5A, modules **502** are inserted downward into the top of chassis **500**, such that a connector disposed at the bottom of module **502** makes contact with a mating connector

located along the inside bottom of chassis **500**. An arrow indicates the direction of insertion. In one embodiment, this connector provides one or more electrical connections between a backplane (not shown) within chassis **500** and electronic components within module **502**. An I/O connector panel module **504**
5 may be disposed at the front of chassis **500**, and may include electrical connections **506** to the backplane and, by extension, to components within the modules **506**.

In the embodiment illustrated in Figure 5A, chassis **500** can accommodate multiple pluggable modules **502**. In one embodiment, the
10 pluggable modules are stacked along an axis that goes through the front and back surfaces of the modules, i.e., stacked in a "front to back" orientation. Side-to-side and front-to-back motion of modules **502** is constrained by the chassis frame and associated heat dissipation structures. Heat generated within modules **502** will be conducted to their front surfaces by skyline
15 structures within the modules, and the heat will be conducted through the front surface of each module to the left, top, and right side surfaces of the modules. From there, the heat may be dissipated away from the modules. Figure 5A shows a chassis without additional heat dissipation structures, but such structures are contemplated by the subject matter described herein. A chassis
20 with heat dissipation means attached is shown in Figure 5B.

Figure 5B illustrates an isometric view of a chassis **500** for holding pluggable modules **502**, showing attached heat dissipation means **508**. In the embodiment illustrated in Figure 5B, heat dissipation means **508** are finned heat sinks that are attached to the top, left, and right sides of chassis **500**.
25 Other possible heat dissipation means include water cooled systems, contact with a cold plate or other refrigeration systems, heat pipes or other devices which use convection or recirculation of a coolant, with or without active pumping systems, and so on.

In contrast to Wedge-Lock® systems, where a locking adaptor is
30 secured within a slot that is machined into the heat sink or cold plate, heat dissipation means **508** does not require precisely machined channels. Instead, heat dissipation means **508** need only make contact with the target surface of the modules – no channels or grooves are needed, reducing manufacturing

costs. In addition, the entirety of the target surface of each module makes contact with heat dissipation device. Because the contact surface area is 5~10 times larger when compared to a Wedge-Lock® system, the flux density is correspondingly lower, i.e., 5~10 times lower than for a Wedge-Lock® system.

- 5 This results in lower heat path loss and therefore better heat dissipation than would be achieved using a Wedge-Lock® system.

Figure 5C illustrates a top view of a modularly pluggable electronic component system according to an embodiment of the subject matter described herein. Figure 5C shows a top view of chassis **500** with left and right
10 heat dissipation means **508A** and **508B**, respectively, attached. In Figure 5C heat dissipation means **508A** and **508B** are finned heat sinks. For clarity, a top heat sink is not shown. In one embodiment, heat sinks may be mounted to the back and bottom surfaces of chassis **500**, also not shown in Figure 5C.

In one embodiment, the frame elements of chassis **500** form an open
15 box-like structure such that the top, left, and right sides of chassis **500** provide an opening or window into which the heat sinks are inserted. The window may have an inset ledge to restrict movement of the heat sink along the plane of the module surfaces with which the heat sink makes contact and against which the heat sink may be firmly mounted. In the embodiment illustrated in Figure 5C, a
20 gasket or seal **510** may be disposed between the heat sink and the inset ledge to provide a seal against dust or other contamination.

In one embodiment, the heat sinks may be mounted to chassis **500** using screws or other attachment means. For example, the heat sinks may be attached to chassis **500** using captive screws inserted through holes in each
25 corner of the heat sink and screwed into threaded holes within the chassis frame. In one embodiment, a compliant washer or spring may be used between the screw head and the heat sink, to compress the heat sink onto surfaces of the modules **M1** through **M5**. For example, in the embodiment illustrated in Figure 5C, heat sink **508A** is compressed against the left surfaces
30 of modules **M1~M5**, and heat sink **508B** is compressed against the right surfaces of modules **M1~M5**. A top heat sink, not shown, would be compressed against the top surfaces of modules **M1~M5**. In one embodiment, a thermal interface material, such as a thermal gasket or thermal paste, may be

located between the modules and the heat sinks, to ensure that the modules and heat sinks contact each other using the maximum surface area available and that these areas make good thermal contact with each other. In an alternative embodiment, a thermal interface material is not used, and the heat
5 sinks make direct contact with the module enclosures.

Alternative embodiments include, but are not limited to, configurations in which the modules are stacked along an axis that goes through the left and right surfaces of the modules, i.e., in a "side by side" orientation, configurations in which the modules are arranged in a row and column or two dimensional
10 (2D) matrix formation, configurations in which the modules are arranged in a three dimensional (3D) matrix formation, configurations in which the modules are arranged in a radial formation, or any other configuration in which one or more of the surfaces of the modules are made available for contact with the heat sinks or other heat dissipation means.

Figure 6A is a elevation cross sectional view of an exemplary modular electronic component as illustrated in Figure 1 installed in a modularly pluggable electronic component system as illustrated in Figure 6A according to an embodiment of the subject matter described herein. In the embodiment illustrated in Figure 6A, a module is seen in cross section, showing a thermally
15 conductive shell **100** within which is housed a circuit board **102** to which a backplane connector **104** is attached. The module has been inserted into chassis **600** in a downward direction, such that backplane connector **104** within the module is electrically connected to a backplane **600** via a mating connector **602** located on the top surface of backplane **600**. In the embodiment illustrated
20 in Figure 6A, backplane **600** is mounted to inside bottom surface **604** of chassis **600** using resilient mounts **606**, which allow backplane **600** to "float" within chassis **500**.

In one embodiment, resilient mounts **606** isolate backplane **600** from chassis **500**, while circuit board **102** is hard-mounted to each module's
30 conductive shell **100**, so as to ensure that the skyline structure makes firm contact between the components on circuit board **102** and the module's conductive shell **100**. In this manner, the circuit board and module are rigidly connected, such that when the module (and other modules) are rigidly attached

to the chassis, e.g., via the compression-mounted heat sinks, the module enclosures, chassis, and heat sinks move together as a unit, while the backplane **600** and backplane connectors **602** move or “float” independently, and are thus isolated from the shock and vibration to which the chassis may be subjected. This isolation protects the critical electrical connections from damage or disruption due to externally applied stresses. Resilient mounts **606** may take many forms, including isolating grommets, a resilient pad or shoe that isolates the entire backplane, etc.

In one embodiment, mechanical stops **608** may protrude from the chassis bottom surface **604** and through backplane **600** to provide a structure against which the modules rest or against which the modules may be pressed. Mechanical stops **608** provide a path for Z-axis strain that bypasses the backplane connectors.

In one embodiment, gathering structures **610** guide the connection of a modules backplane connector **104** to its mating connector **602** during insertion of the module into chassis **500**. In the embodiment illustrated in Figure 6A, a guide pin, post, or cone **610** mounted to backplane **600** may align with cavities within or associated with backplane connector **104** during insertion so as to place the two connectors in proper alignment. Alternative gathering structures **610** may be used. For example, guide pins, posts, or cones **610** may be integral to mating connector **602**, or they may be separate from mating connector **602**. Likewise, the positions of the male and female portions of the connectors may be swapped, etc.

The combination of mechanical stops **608** and gathering structures **610** results in a modularly pluggable electronic component system which has a very reliable electrical connection between the modules and backplane **600**. The Z-axis stress path bypasses electrical connectors **104** and **602**, and the X-axis and Y-axis stresses are borne by the chassis and modules together. Even if X-axis, Y-axis, or Z-axis stress is somehow transferred through electrical connector **104** on circuit board **102** to electrical connector **602** on backplane **600**, backplane **600** floats on resilient mounts **606**, which absorb the stress by allowing connectors **104** and **602** to move in tandem, with the result that there is no force present that might separate the two connectors from each other or

cause separation of a connector from the circuit board or backplane to which it is mounted. All of these features contribute to form a system in which failure of electrical connection between a module and the backplane due to stress, vibration, or separation is greatly reduced.

5 Figure 6B illustrates a backplane with module connectors of a modularly pluggable electronic component system according to an embodiment of the subject matter described herein. Backplane **600** is mounted within a tray structure made up of the chassis bottom surface **604** along with left and right walls **612**. In one embodiment, the top surface of backplane **600** includes
10 module connectors **602** and clearance holes through which mechanical stops **608** protrude. Although not shown in Figure 6B, each module **100** may have a mating backplane connector **104** on the bottom surface of the module. In the embodiment illustrated in Figure 6B, tray walls **612** include alignment structures **614** that align within correspondingly shaped channels or notches **616** in each
15 module enclosure **100**. During insertion operations, alignment structures **614** start gathering and aligning the modules being inserted before guide pins **610** (not shown in Fig. 6B) begin to engage. Alignment structures **614** and channels **616** may help guide module **100** as it is being inserted into the chassis, and once the modules are inserted may provide stability to the
20 modules, e.g., to restrict motion in the X-axis and/or Y-axis.

Alignment structures **614** may be located on any surface where the module and chassis may come in contact with each other, such as at the top or middle of the module enclosure, etc. Alignment structures **614** may be designed to ensure a desired separation between modules within the chassis,
25 e.g., to provide thermal isolation from one module to another or to provide each module with additional isolation against shock or vibration.

The pitch or spacing of backplane connectors **602** may also vary according to configuration or need. For example, in one embodiment, backplane **600** may be designed to accept only 12.5mm modules, while in
30 another embodiment, backplane **600** may be designed to accept only 19mm modules. Alternatively, backplanes **600** may be produced to accept a mix of module sizes including 12.5mm, 19mm, or any other module size deemed appropriate. The subject matter described herein is not limited to the specific

module dimensions described above; the thermally conductive module enclosure and thermal skyline structure can be implemented in modules having larger or smaller dimensions as well, with corresponding changes to the chassis size.

5 Figure 7 is a backplane interconnect diagram for a modularly pluggable electronic component system according to an embodiment of the subject matter described herein. Figure 7 illustrates an embodiment wherein a chassis includes five slots and a system connector panel. In this embodiment, slot 1 is occupied by a power supply module which provides power to remaining slots in
10 the chassis via the four power supply lines labeled PWR(4) and provides both a power indication signal (status/LED) and a power connection (9-45VDC) to the system connector panel. Slot 2 is occupied by a CPU module that provides serial ATA, or SATA, connections to each of the three slots 4 through 5 and to the system connector panel, and also provides PCI-E connections to each of
15 slots 4, 4, and 5. The CPU module also provides an Ethernet (ENET) connection, a video connection, and two USB connections to the system connector panel. The system connector panel provides both data input/output (DIO) and RF connections to each of the modules in slots 4, 4, and 5. In the embodiment illustrated in Figure 7, slots 4, 4, and 5 may accept a 12.5mm
20 module or a 19mm module.

 The configuration shown in Figure 7 is not the only configuration contemplated by subject matter described herein. Other configurations and electrical connections are possible, depending on the backplane used. Together with the tray structure illustrated in Figure 6B, this gives rise to the
25 possibility of a system having a modular backplane, as well, e.g., a system wherein various backplanes may be swapped in and out of the chassis. The same principle may apply to the system connector panel, e.g., the system connector panel may be a replaceable module as well, with various combinations of connectors and connections as needed for the particular
30 application. The connector panel may plug in along the "Z" axis or may plug in "endwise" on the "Y" axis. In one embodiment, a chassis may have more than one backplane. In one embodiment, each backplane may have connectors on both sides, e.g., in a two story, 5-up, 5-down configuration or be endwise

contiguous, along Y axis. Other numbers of slots are also contemplated. For example, there may be various chassis sizes, having larger or smaller numbers of slots.

- It will be understood that various details of the subject matter described
- 5 herein may be changed without departing from the scope of the subject matter described herein. Furthermore, the foregoing description is for the purpose of illustration only, and not for the purpose of limitation.

CLAIMS

What is claimed is:

1. A modular electronic component, comprising:
 - a circuit board having disposed thereon one or more electronic components;
 - an enclosure for housing the circuit board, the enclosure comprising a thermally conductive shell having front and back surfaces being substantially parallel to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, left and right surfaces being substantially perpendicular to the plane of the circuit board and being disposed on opposite sides of the circuit board from each other, and opposing top and bottom surfaces being substantially perpendicular to the left and right surfaces and substantially perpendicular to the front and back surfaces and being disposed on opposite sides of the circuit board from each other; and
 - a thermal shunt comprising a thermally conductive material disposed between the one or more circuit board components and the front surface of the enclosure for providing a thermally conductive path between at least one of the one or more electronic components and the front surface of the enclosure, wherein the front surface of the enclosure conducts heat to at least one of the top, left, and right surfaces of the enclosure.
2. The modular electronic component of claim 1 wherein the thermally conductive shell comprises a metal material.
3. The modular electronic component of claim 1 wherein the thermal shunt comprises at least one of a thermally conductive paste, a thermally conductive fluid, a thermally conductive plastic, and a metal.
4. The modular electronic component of claim 1 wherein the thermally conductive shell comprises a thermally conductive bottom surface and wherein the front surface of the enclosure conducts heat to the bottom surface of the enclosure.
5. The modular electronic component of claim 4 wherein the modular electronic component is a stand-alone module that is self-sufficient.

6. The stand-alone module of claim 5 comprising at least one of a power source and a power converter contained within the enclosure for providing power to the one or more circuit board components.
7. The modular electronic component of claim 1 wherein the enclosure is sealed.
8. The modular electronic component of claim 7 wherein the enclosure contains a thermally conductive, electrically insulating substance for conducting heat from the one or more electronic components to at least one of the front, top, left, and right surfaces of the thermally conductive shell, wherein the thermally conductive, electrically insulating substance comprises at least one of a liquid, a gel, a paste, a powder, and a solid.
9. The modular electronic component of claim 1 wherein a first electrical connector for providing at least one electrical connection to the circuit board is disposed within the bottom surface of the enclosure.
10. The modular electronic component of claim 9 wherein the circuit board is secured within the thermally conductive shell and wherein the first electrical connector is mounted to the circuit board.
11. The modular electronic component of claim 1 wherein the circuit board includes a second electrical connector for providing at least one electrical connection to a daughter circuit board also contained within the thermally conductive shell.
12. The modular electronic component of claim 11 wherein the daughter circuit board comprises a circuit board that substantially conforms to the nanoETXexpress standard.
13. A modularly pluggable electronic component system, comprising:
 - a chassis for housing a plurality of modules that house circuit boards, each module comprising a thermally conducting enclosure having front, back, left, right, and top surfaces and a circuit board disposed within the enclosure, wherein the plane of the circuit board is substantially parallel with the plane of the front and back surfaces, wherein the circuit board includes one or more components, and wherein the front surface of the module provides a path to conduct heat

from the one or more components to at least one of the top, left, and right surfaces of the module;

5 a backplane disposed within a lower portion of the chassis for providing one or more electrical connections to the modules, the backplane having upward-facing electrical connectors for connecting to downward-facing electrical connectors disposed along the bottom surface of the modules that are inserted downward into the chassis; and

10 heat dissipation means being in physical contact with and for conducting heat away from the at least one of the top, left, and right surfaces of the modules.

14. The modularly pluggable electronic component system of claim 13 wherein at least one of the modules for housing circuit boards comprises a circuit board secured within the module enclosure and includes at least one electrical connector, disposed within the bottom surface of the module, for providing at least one electrical connection between the circuit board and the backplane.

15. The modularly pluggable electronic component system of claim 13 wherein the heat dissipation means comprises a heat sink.

16. The modularly pluggable electronic component system of claim 15 wherein the heat sink includes fins for radiating heat.

17. The modularly pluggable electronic component system of claim 15 wherein the heat sink contains a recirculating liquid and/or gas.

18. The modularly pluggable electronic component system of claim 13 wherein the heat dissipation means comprises a compression loaded side plate heat spreader.

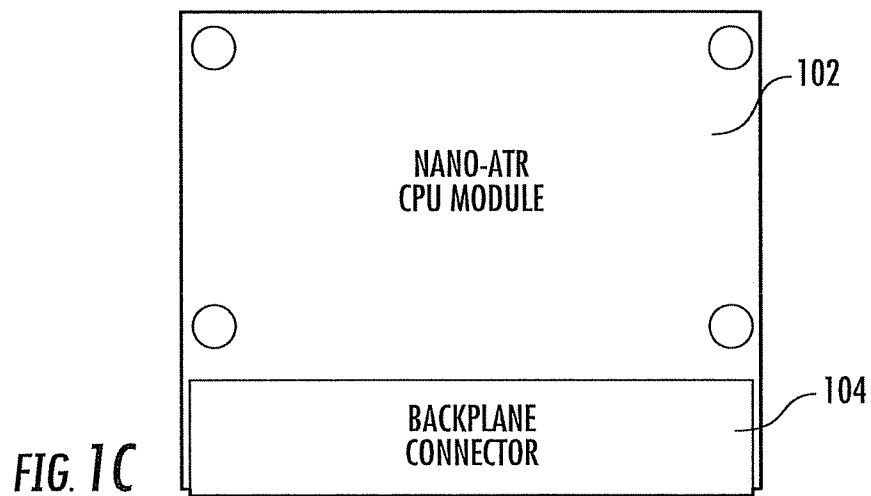
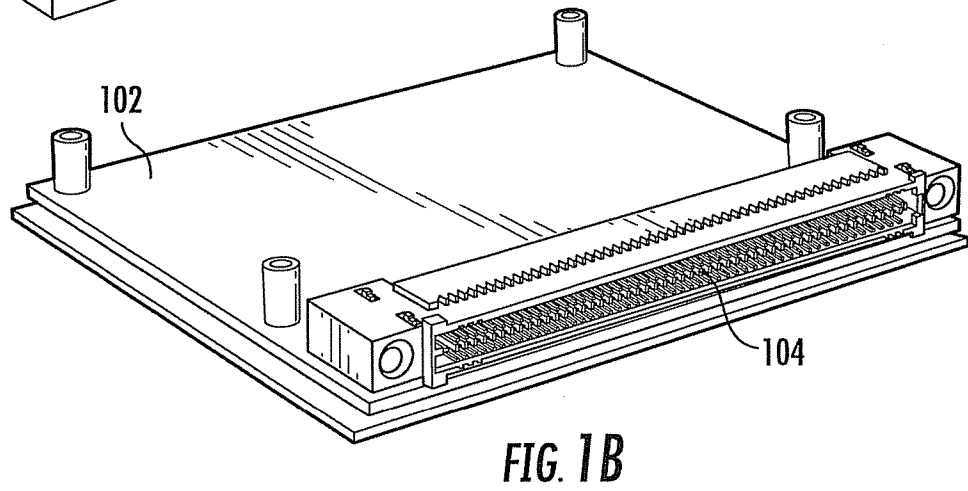
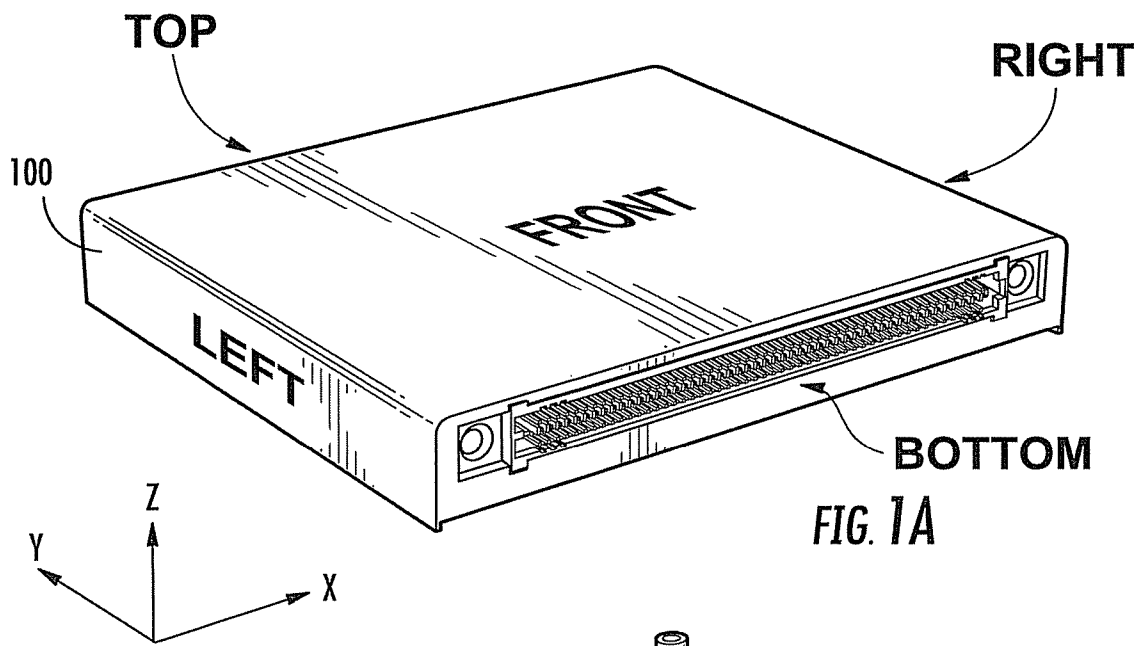
19. The modularly pluggable electronic component system of claim 13 wherein the inserted modules are stacked along an axis through the front and back surfaces of the modules.

20. The modularly pluggable electronic component system of claim 13 wherein the modules are interlocked within the chassis.

21. The modularly pluggable electronic component system of claim 13 wherein the chassis comprises a tray for mounting the backplane and for providing alignment to the modules.

22. The modularly pluggable electronic component system of claim 21 wherein the tray walls include guides for aligning modules during insertion of the modules and for maintaining the position of the modules within the chassis.
- 5 23. The modularly pluggable electronic component system of claim 13 comprising means for orienting the modules to the chassis.
24. The modularly pluggable electronic component system of claim 23 wherein means for orienting the modules to the chassis comprises at least one of:
- 10 conical or beveled structures proximate to the backplane connectors for engaging in receptacles disposed within the bottom surface of the modules; and
- conical or beveled structures disposed on the bottom surface of each module for engaging in receptacles proximate to the backplane
- 15 connectors.
25. The modularly pluggable electronic component system of claim 23 wherein means for orienting the modules to the chassis comprises means for positioning modules in a predetermined orientation or location with respect to each other.

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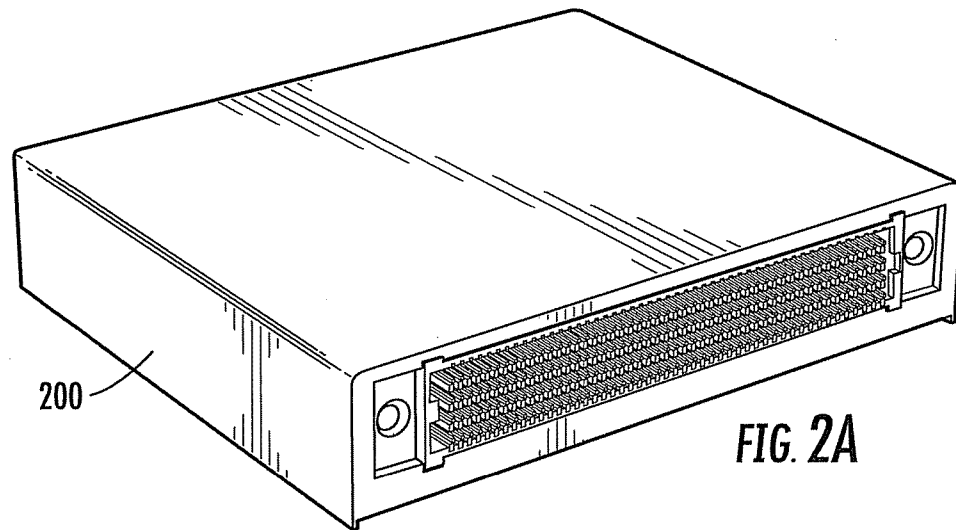


FIG. 2A

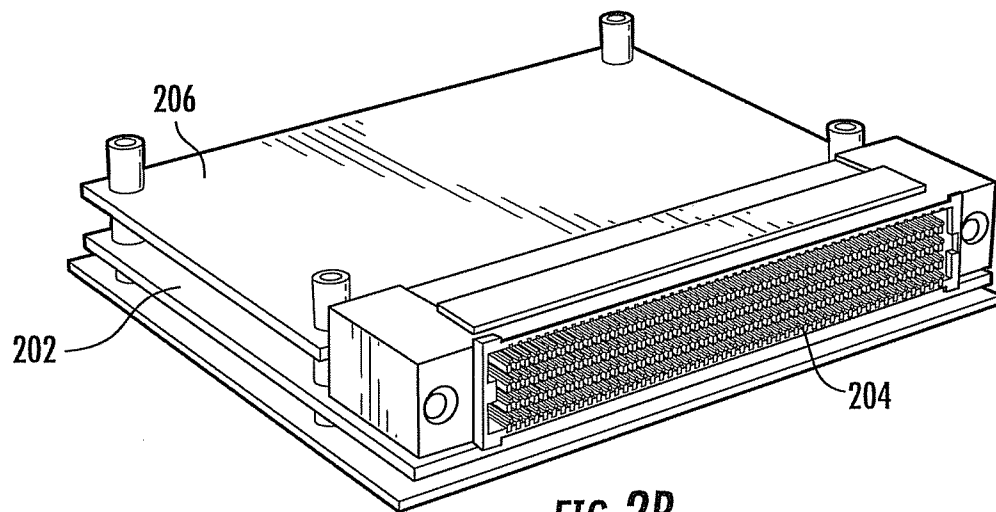


FIG. 2B

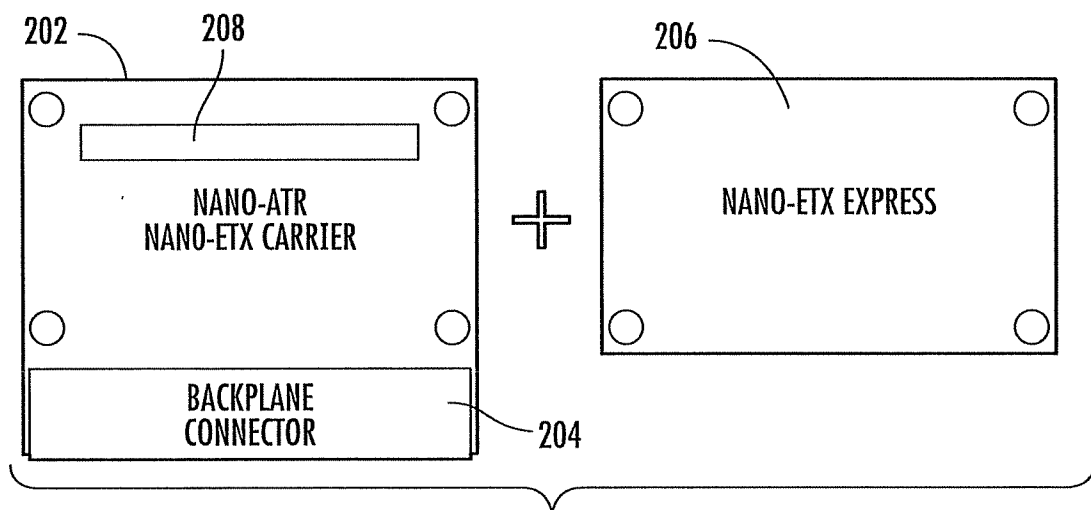


FIG. 2C

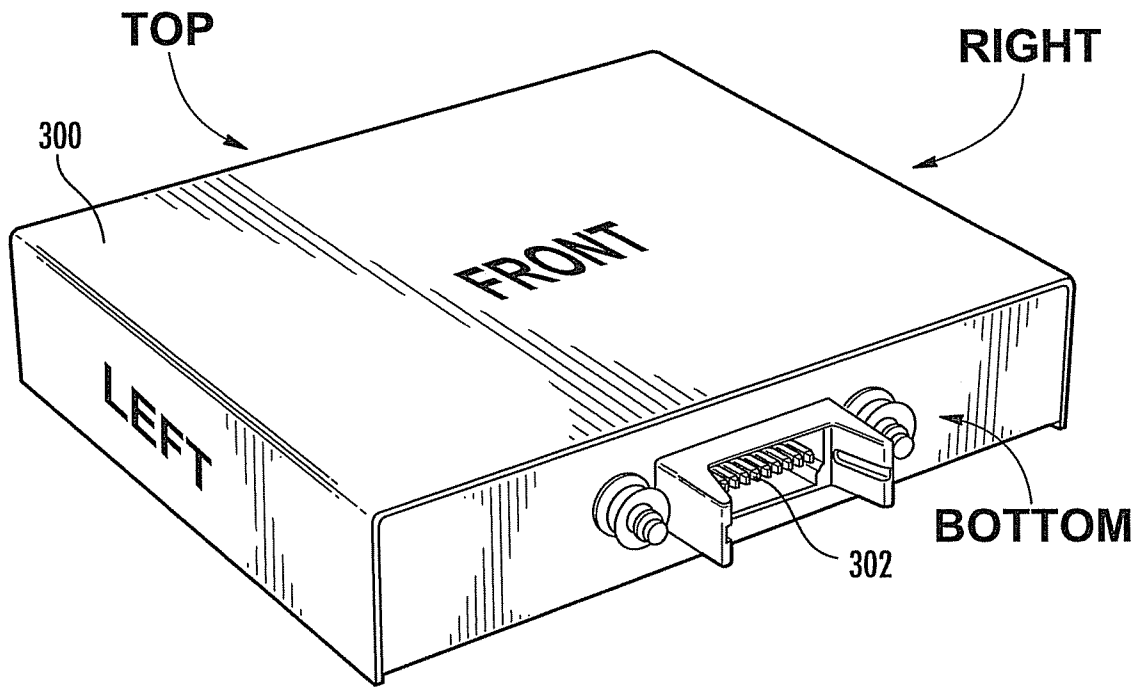


FIG. 3

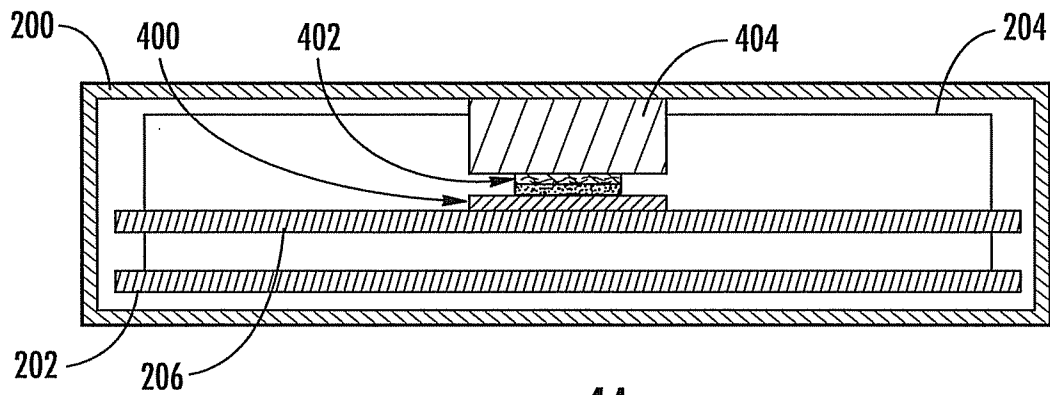


FIG. 4A

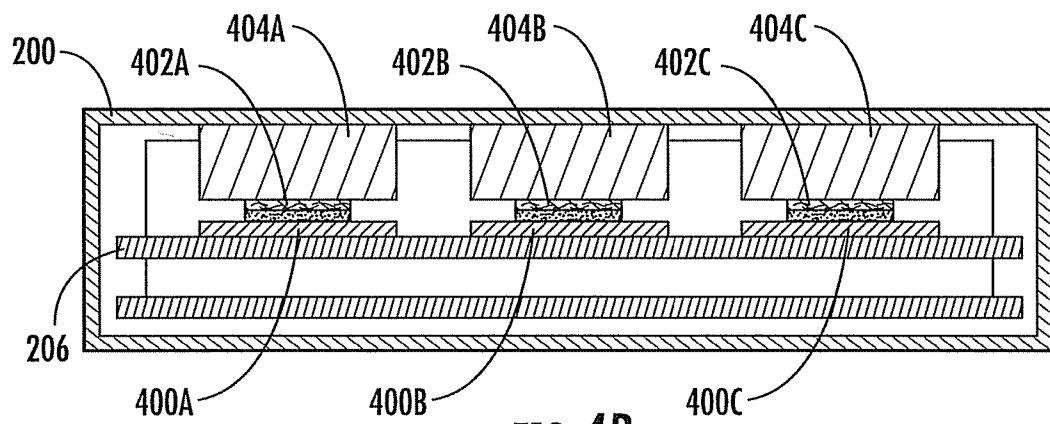


FIG. 4B

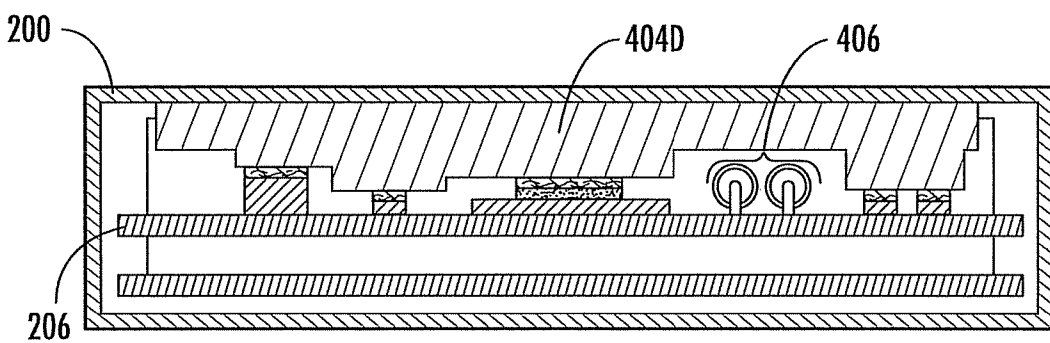
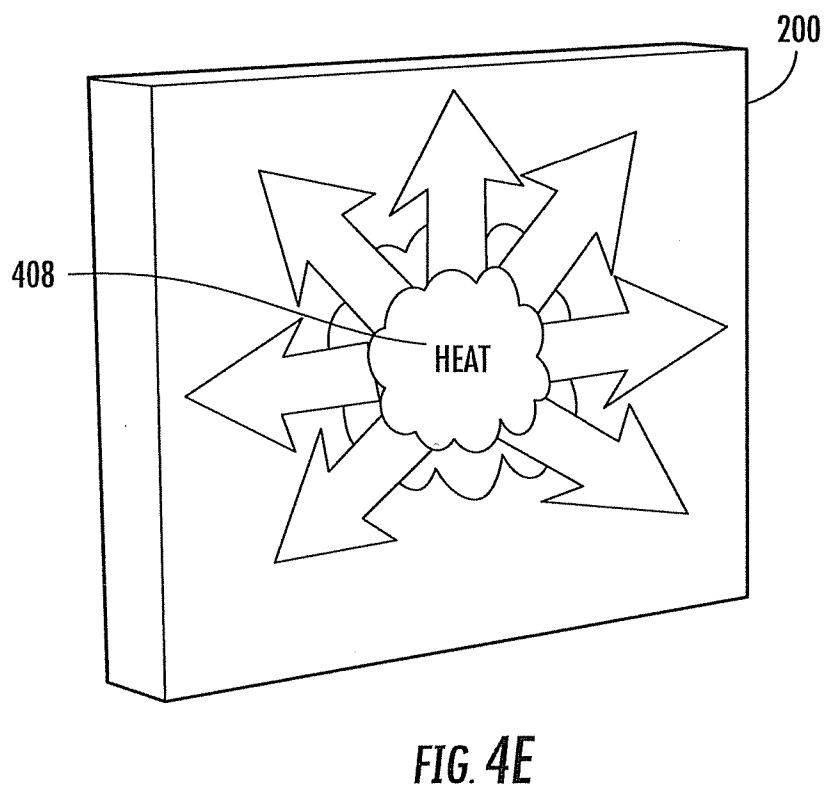
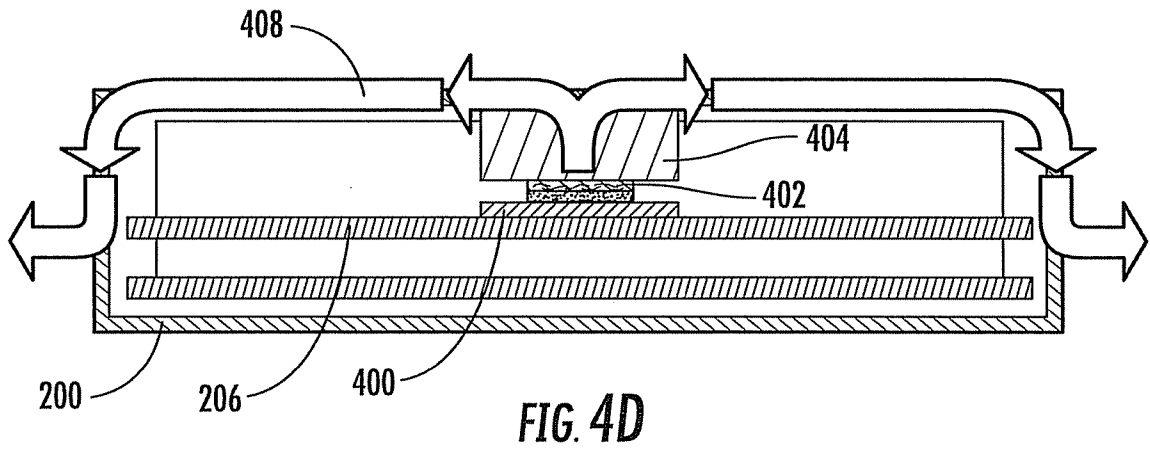


FIG. 4C



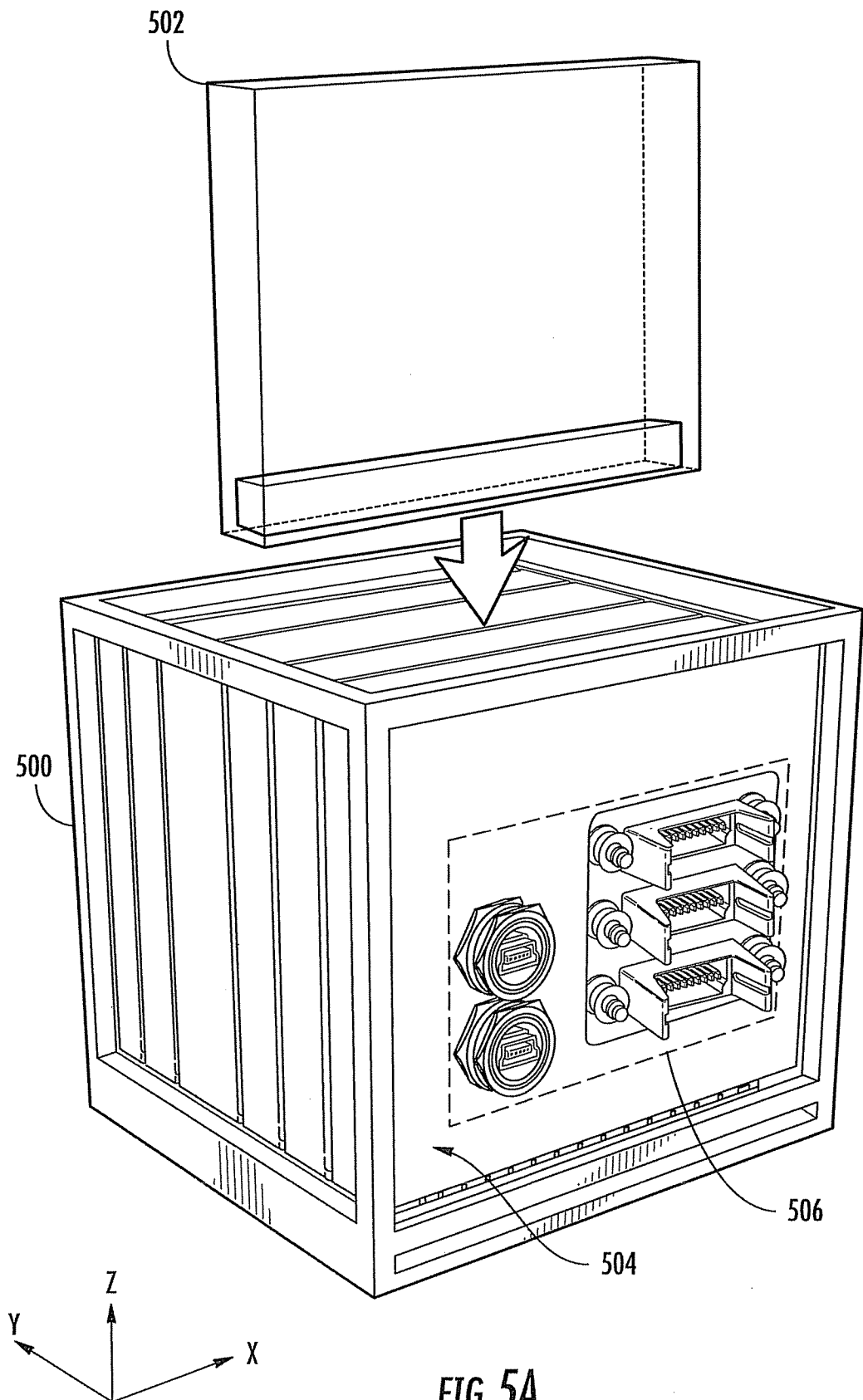
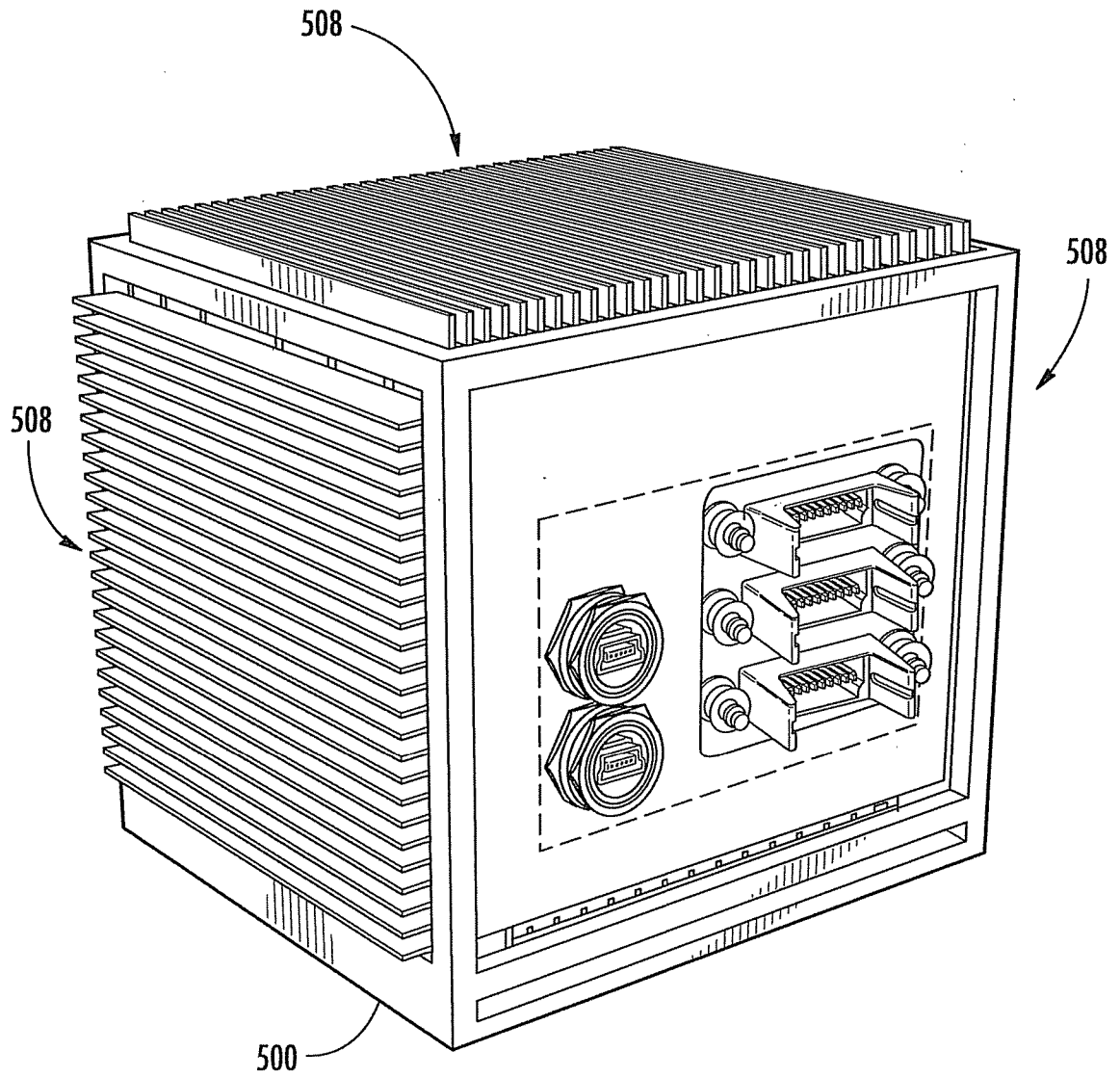


FIG. 5A

**FIG. 5B**

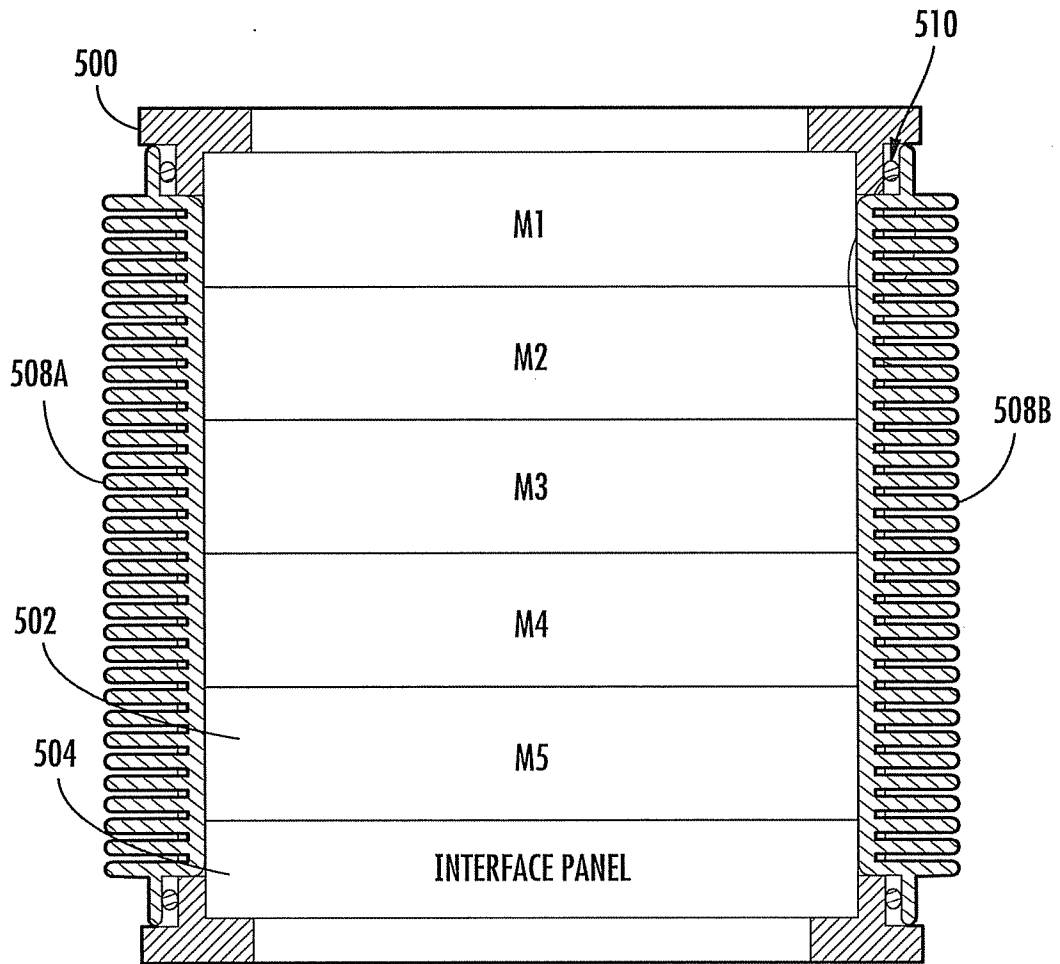


FIG. 5C

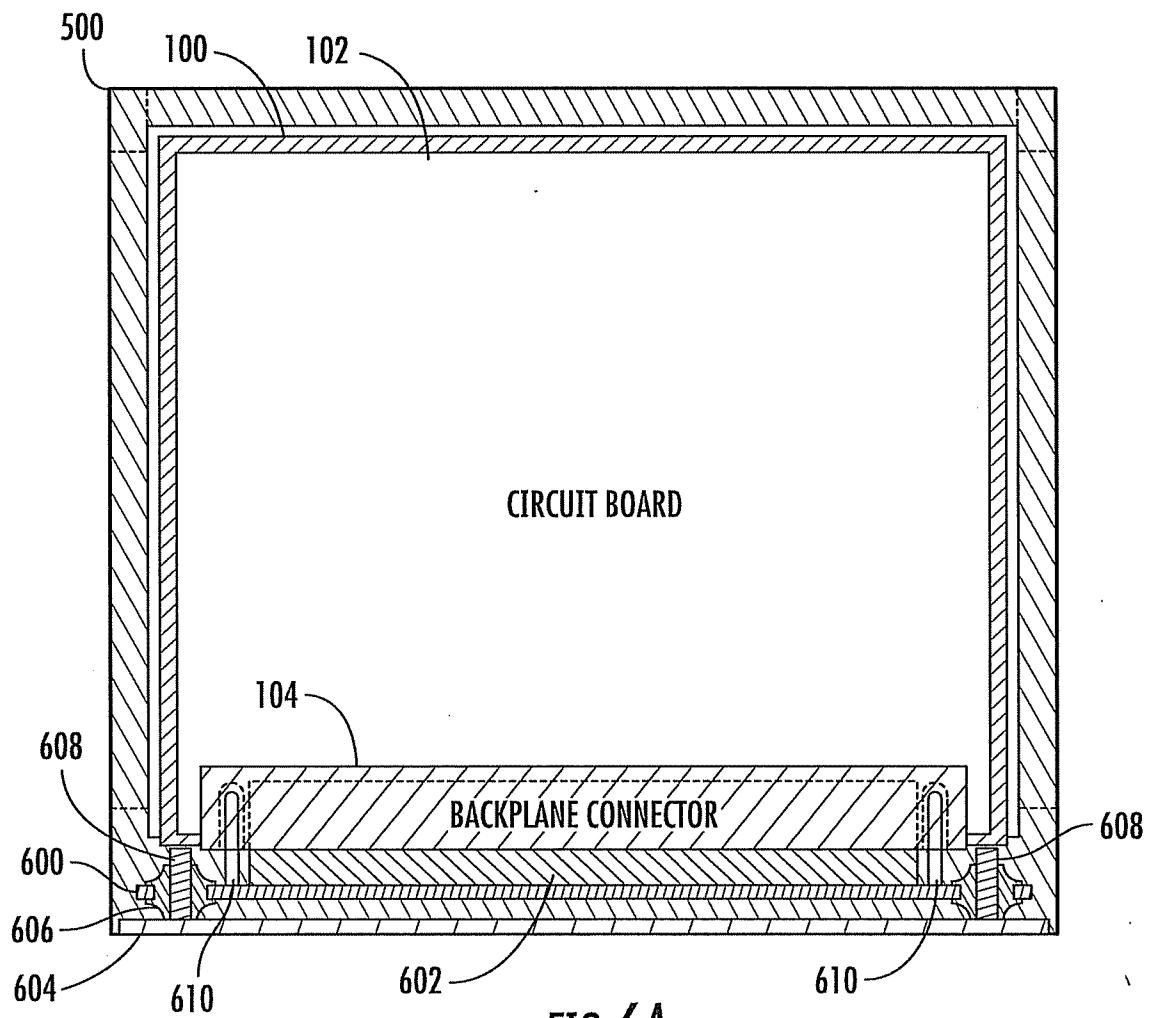


FIG. 6A

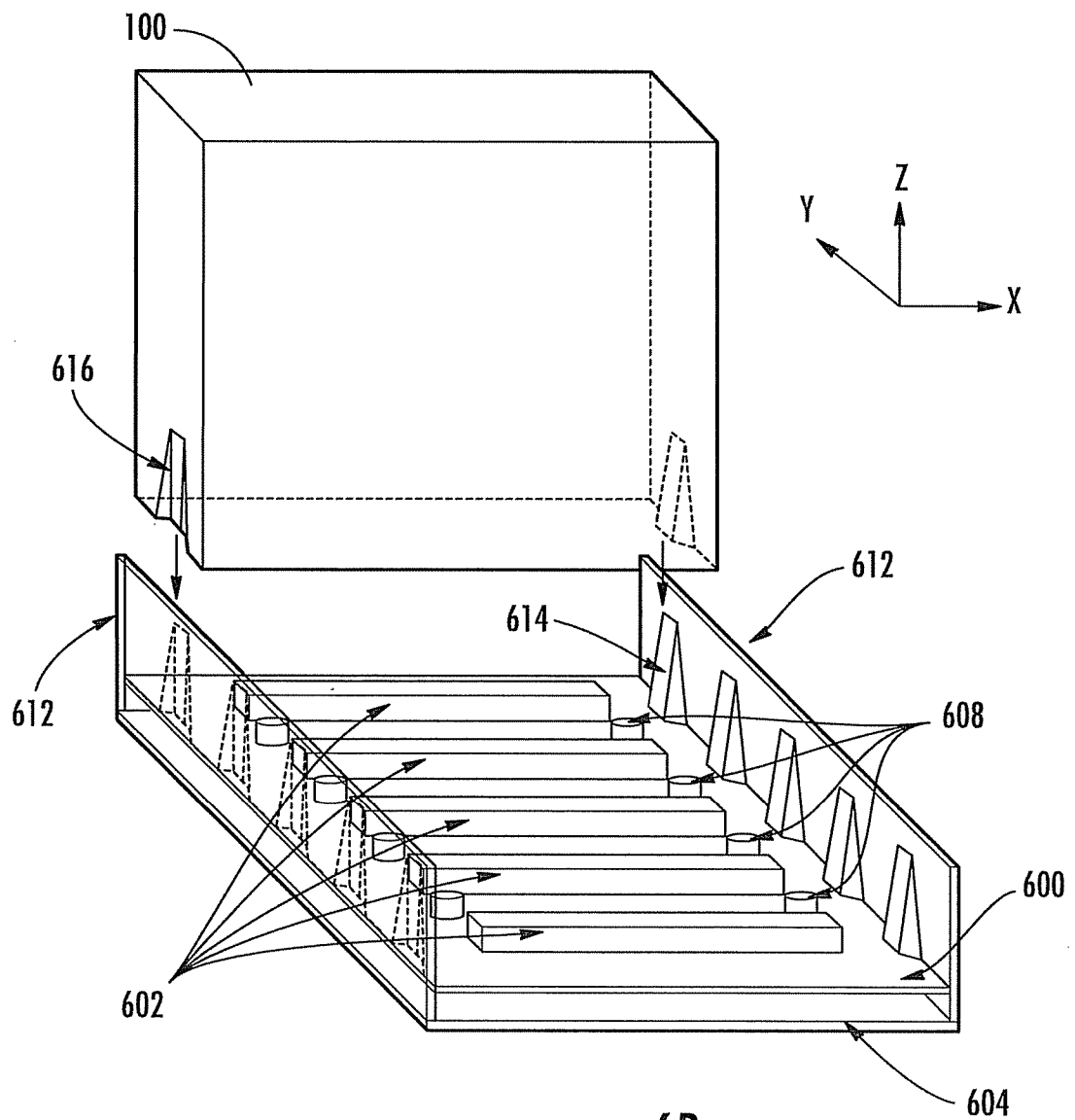
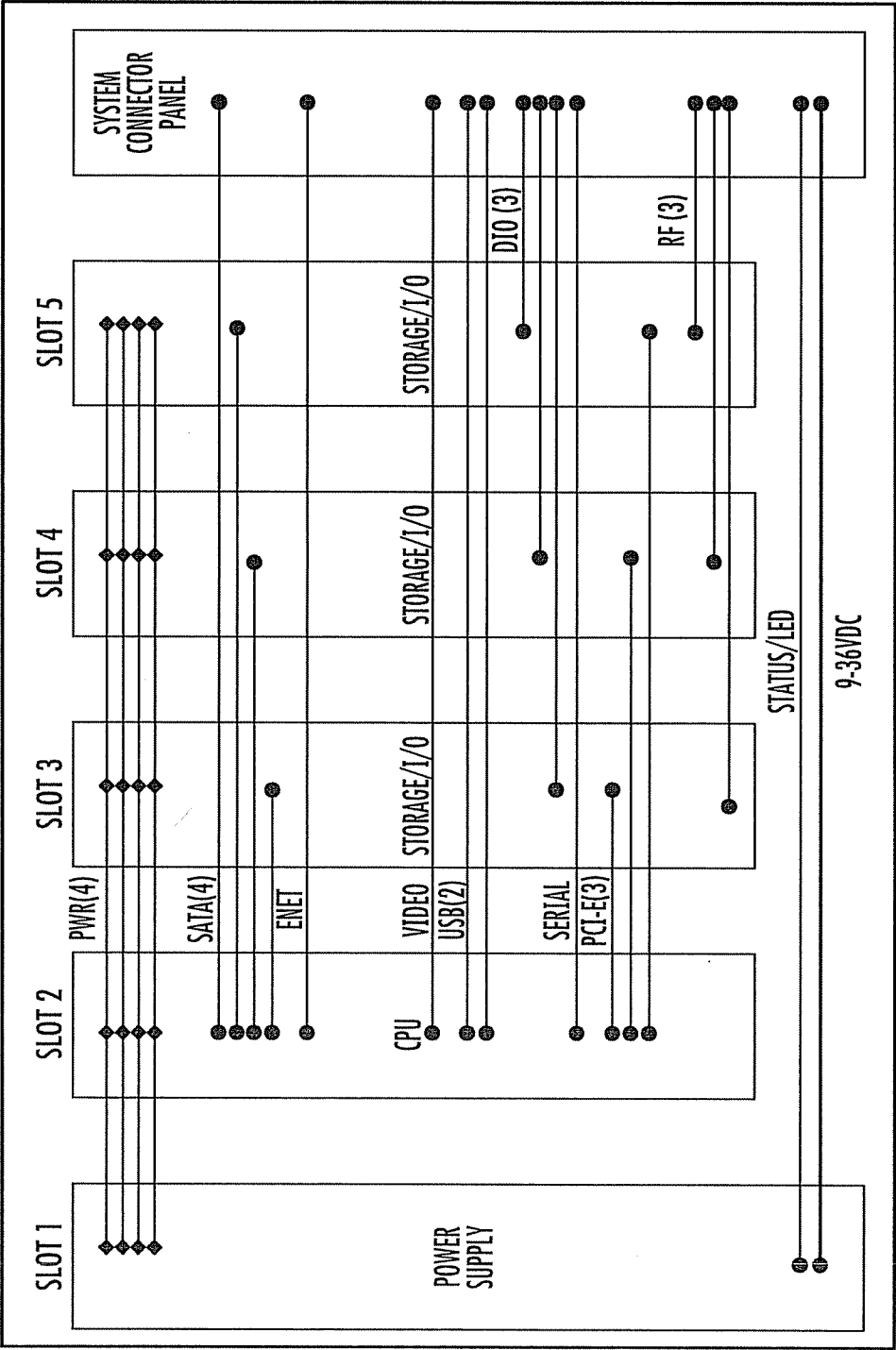


FIG. 6B



I/O SLOTS CAN BE 12.5mm (4-ROW) OR 19mm (8-ROW) MODULES

FIG. 7