# United States Patent

**Rathjen et al.**

[15] **3,648,113**

[45] **Mar. 7, 1972**


## [54] ELECTRONIC ASSEMBLY HAVING COOLING MEANS FOR STACKED MODULES


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[52] **U.S. Cl.** ........................**317/100,** 174/15 R, 317/101 CM

[51] **Int. Cl.** ........................**H05k 7/20**

[58] **Field of Search** ........................174/15 R, 16 R, 16 HS; 317/100, 101 DH, 101 CM, 101 CX



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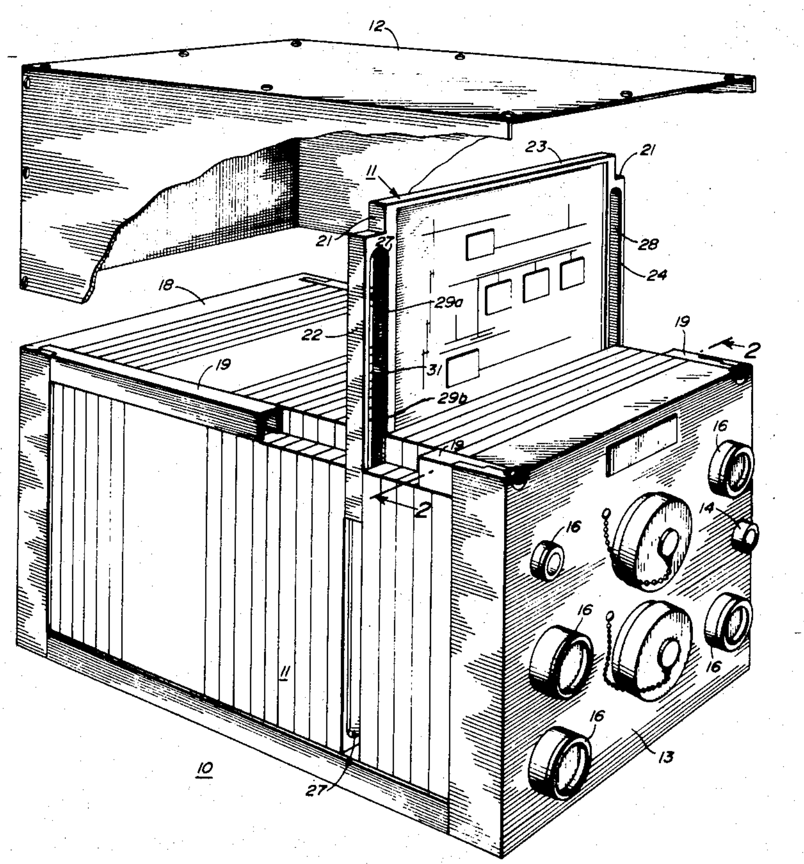
[57] **ABSTRACT**

A modular electronic system includes a plurality of stacked electronic units. The stacked units have a first cavity therethrough along one edge thereof, and a second cavity therethrough along an opposite edge thereof. Each of the units has a spacing joining the two cavities. A first mounting plate has an orifice therethrough for communicating with the first cavity, and a second mounting plate has an orifice therethrough for communicating with the second cavity. Means are provided for clamping the fist mounting plate, the stacked units, and the second mounting plate together, so that cooling fluid can be passed from an exterior source through the first mounting plate orifice, through the first cavity, through in parallel all of the spacings, through the second cavity, and exiting through the second mounting plate orifice.


**7 Claims, 7 Drawing Figures**



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3 Sheets-Sheet 1

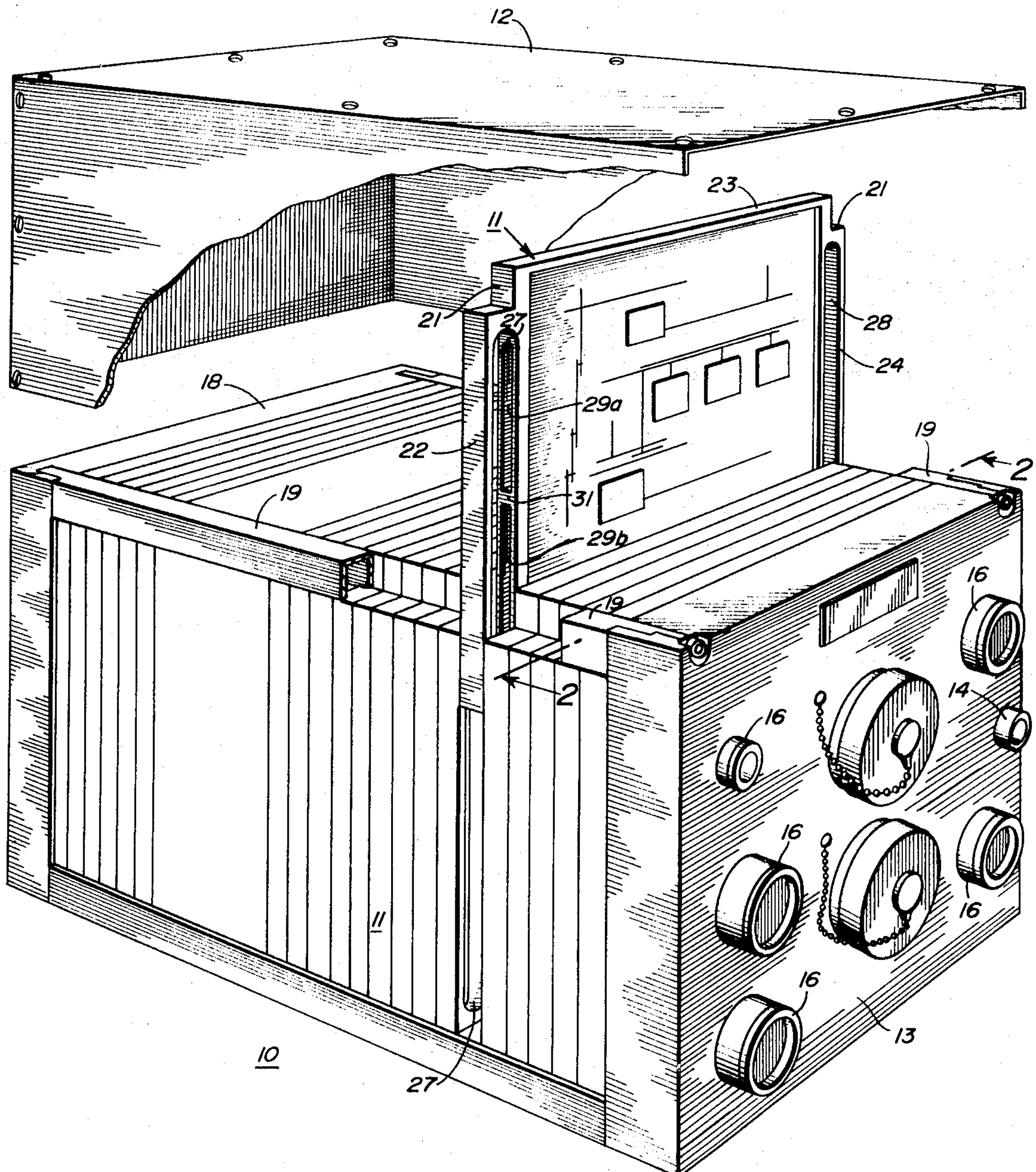


Fig. 1

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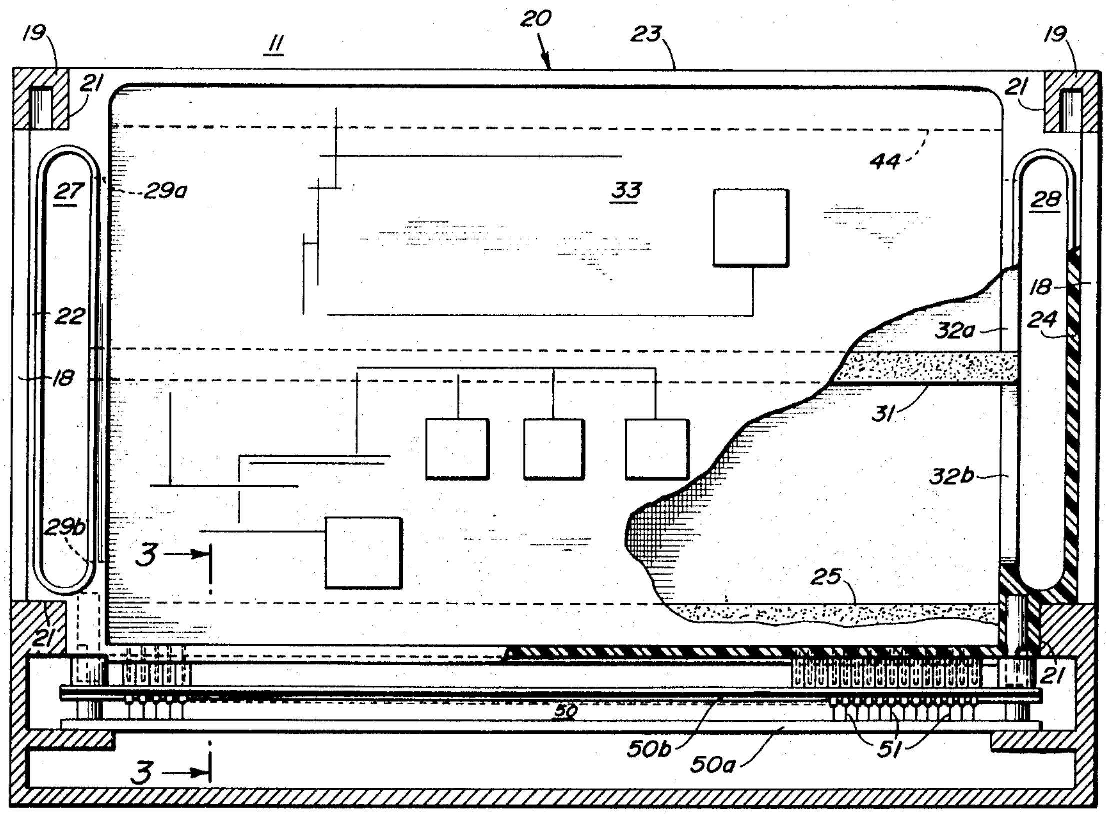


Fig. 2

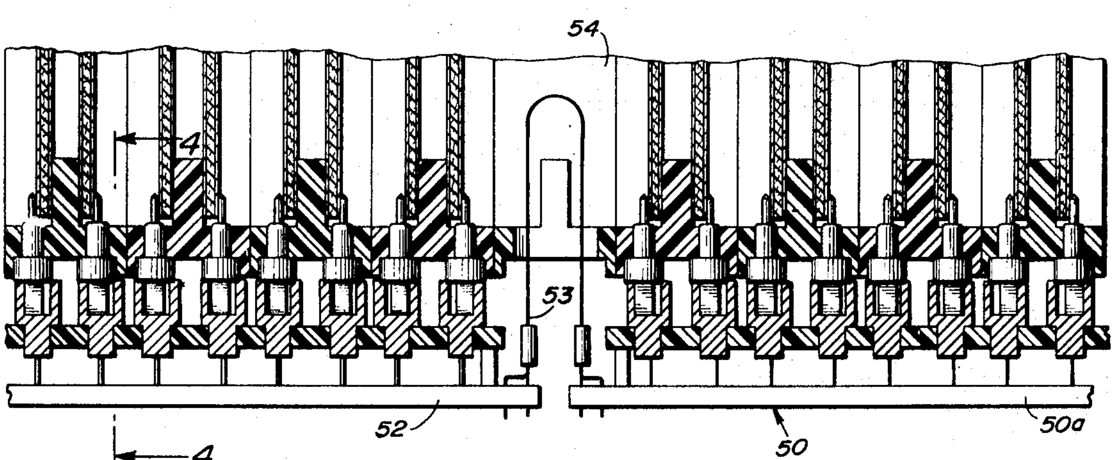


Fig. 3

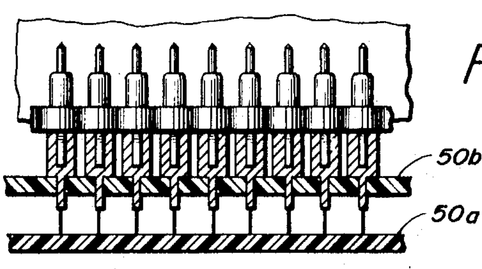


Fig. 4

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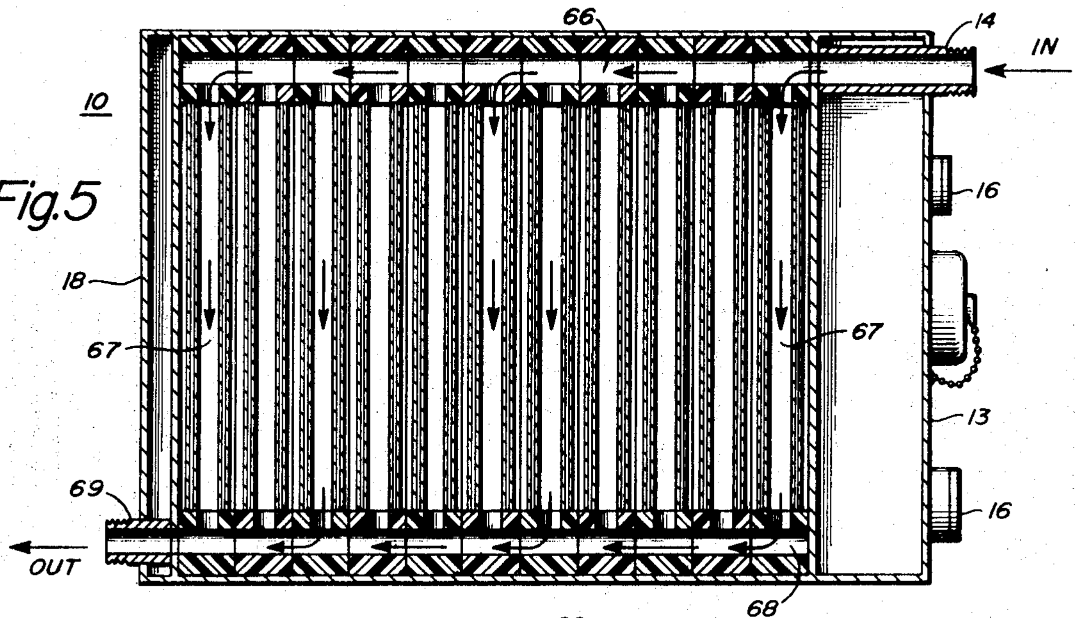


Fig.5

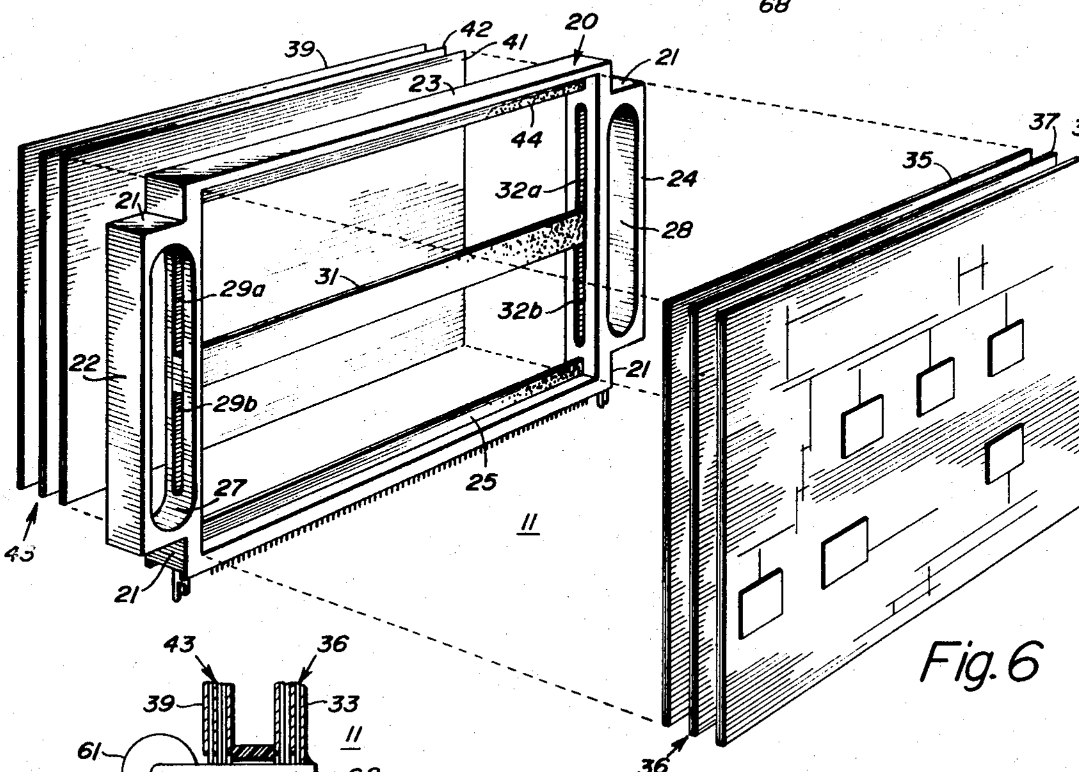


Fig.6

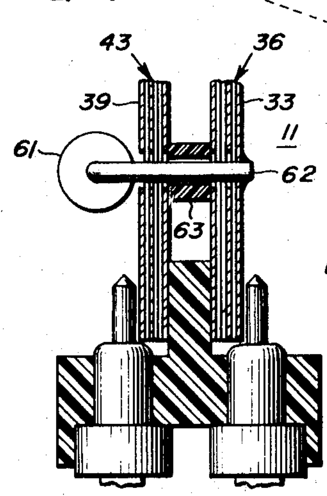


Fig. 7

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# ELECTRONIC ASSEMBLY HAVING COOLING MEANS FOR STACKED MODULES

## BACKGROUND OF THE INVENTION

This invention relates to modular electronic systems and, in particular, relates to a high-density electronic packaging arrangement which provides for efficient heat dissipation and can withstand high vibration and shock. Accordingly, the general objects of the invention are to provide new and improved apparatus of such character.

Various electronic packages have been designed in the past with various degrees of effectiveness for housing electronic components and for dissipating the heat generated thereby.

In the U.S. Pat. No. 3,395,318, issued July 30, 1968 to Lothar Laermer (one of the applicants hereof) and Arthur J. Pretty and Philip Gray and assigned to the assignee of this invention, a circuit board card arrangement for the interconnection of electronic components is described. The aforesaid patent relates to a circuit board for the interconnection of electronic components such as flat packs and discrete components, and includes a flat rectangular plate with an insulating coating having a plurality of apertures wherever necessary for passing leads. Around the plate is a metal frame and an extension which may be coupled to a heat exchanger. Over one or both faces of each flat side of the plate is an epoxy resin and an X–Y circuit board with X-lines on one side and Y-lines on the other. Electrostatic shielding is provided by applying a ground termination to the plate.

Apparatus, constructed and operated in accordance with the teachings of the aforementioned patent, utilized a plurality of card units in which each card unit contained a central aluminum core and two epoxy circuit boards laminated to each side of the core. The aluminum body of each card unit was connected by contacts to the outside surface of a frame. The outside surface of the frame was formed in a corrugated manner to act as a heat exchanger so that, when air was blown past the outside surface of the frame, the large corrugated surface area would give up heat to effectively cool the entire electrical package. Air would be passed from one card, to the next card, and to the succeeding cards in a manner which could be referred to as a series type heat exchanger. With such a system (as a series-type heat exchanger), when air is blown from one side to the opposite side, by the time the air gets to the opposite side, the air would be hot and insufficient cooling might take place at the rear of the unit. Hence, such an electronic package is limited to comparatively low-wattage ratings per card, for example, to about 3 watts of power per card. Disadvantageously, however, such a system does not work well in dealing with higher wattages, for example, in the order of 20 watts per card.

At the bottom of such apparatus, an integral, interconnect board, otherwise termed a "motherboard," contained all the interconnect connections in one solid block for all the modular circuit board units. Disadvantageously, the motherboard was fixed dimensionally, was not easily changeable, and would necessitate a redesign if it was desired that additional circuit boards be added to the overall system.

In prior systems, flat printer circuit pins or male contacts were oriented and aligned with the flat surfaces of the pins parallel to the surface of the board. Each card was individually retained in the motherboard by corresponding female contacts.

It is desired to provide an electrical system which occupies as minimum a volume as possible. When electrical circuitry is placed into a housing which is close quartered so as to utilize a small volume, a heat problem arises. Thus, it is desired to provide for efficient dissipation of the heat. In addition, in complex electronic circuits, such as computers, it is desired to make the system expandable. Also, it is desired to provide a system which is able to withstand high shock and vibrations for rugged commercial or government applications.



## SUMMARY OF THE INVENTION

Another object of this invention is to provide new and improved modular electronic systems.

It is another object of this invention to provide new and improved modular electronic systems in which the thermal resistance between the source of heat and airflow passing by the heat exchanger is less than corresponding designs of the prior art.

Another object of this invention is to provide new and improved modular electronic systems which can withstand high shock and vibration.

Still another object of this invention is to provide new and improved modular electronic systems in which the systems can be made expandable by adding additional components thereto or by deleting several components therefrom, without necessitating a complete redesign of such a structure.

With these and other objects in mind, a modular electronic system can be provided including a plurality of stacked electronic circuit units having a first cavity through the stack along one edge thereof and a second cavity through the stack along an opposite edge thereof. Each of the units has a spacing joining the two cavities. A first mounting plate is provided having an orifice therethrough for communicating with the first cavity. A second mounting plate has an orifice therethrough for communicating with the second cavity. Means are provided for clamping the first mounting plate, the stacked units, and the second mounting plate together so that cooling fluid can be passed from an exterior source through the first mounting plate orifice, through the first cavity, through in parallel all of the spacings, through the second cavity, and exiting through the second mounting plate orifice.

More specifically, the invention contemplates a modular electronic system including a first plurality of stacked electronic circuit units wherein each of the units includes a first laminate formed by a first substantially rectangular printed circuit board having components thereon, a first substantially rectangular thin sheet of heat conductive material, and insulating means for laminating the printed circuit board to the printed sheet. The unit further includes a second laminate similarly formed. A hollow heat conductive frame holds the two laminates, one on each side thereof, wherein the sheets of both laminates are oriented inwardly with respect to the frame and separated from each other to form a spacing between them, the frame being formed in a generally rectangular configuration having four border members. A first elongated aperture is formed through and along one of said border members from one side of the frame to the opposite side thereof. A slot is provided joining the first elongated aperture to the spacing. Similarly, a second of the border members nonadjacent to the first member has an elongated aperture formed therethrough and therealong from one side of the frame to the opposite side thereof, and further having a slot joining the second elongated aperture to the spacing. The laminates are fixed to both sides of the frame. The modular electronic system further includes a front mounting plate in contact with one end of the stacked electronic units having an orifice therethrough for communicating with the first elongated apertures of the frames, and a back mounting plate in contact with the opposite end of the stacked electronic units having an orifice therethrough for communicating with the second elongated apertures of the frames. The front and back mounting plates the the intermediately oriented stacked electronic units are clamped so that cooling fluid can be passed from an outside source, serially through the front mounting plate orifice, through a plenum formed by the stacked first elongated apertures of the circuit units, through in parallel the first slots of all the frames, then the spacing of all the frames, thereby directly cooling the sheets and indirectly cooling the boards and the components on the boards, and then the second slots of all the frames, serially through a cavity formed by the stacked elongated apertures of the circuit units, and exiting through the back mounting plate orifice.

In certain features of the invention, the printed circuit boards have male electrical contacts disposed along a third of the border members and further include electrical interconnecting means including female electrical contacts for mating with the male contacts. Each male electrical contact has a width substantially greater than its thickness and is so oriented with its width perpendicular to the surface of the printed circuit boards. The corresponding mating female electrical contacts are tight fitting with respect to thickness and loose fitting with respect to width.

Additional features of the invention include electrical interconnecting means having a first electrical interconnect board containing female electrical contacts for communicating with the corresponding male contacts of the first plurality of the adjacent stacked electronic circuit units, a second electrical interconnect board containing female electrical contacts for communicating with corresponding male contacts of a second plurality of adjacent stacked electronic units and flexible electrical wiring tape for joining the first interconnect board to the second interconnect board. The modular system would further include a dummy electronic circuit unit having a plate having an elongated aperture along two opposite borders thereof so as to align, plenum and cavity, with the first and second pluralities of stacked units, said plate having a concavity within the third border thereof, so as to receive a loop of the tape therewithin. The wiring tape would have a length exceeding a value L +T wherein L is a value representing the width of the dummy plate and wherein T is a value representing the maximum dimensional tolerance error in width that could occur by stacking a first plurality of adjacent stacked circuit units together.

In an additional feature of the invention, each of the stacked electronic circuit units contains a heat conductive structural member joining one of the border members intermediate the first elongated aperture to the second of the border members intermediate the second elongated aperture. The width of the various structural members are optimized so as to vary the cross-sectional area of the spacings of each unit and to control the corresponding coolant fluid flow rate therebetween so as to optimize the degree of cooling of each circuit unit.

## BRIEF DESCRIPTION OF THE DRAWING

Other objects, advantages, and aspects of the invention will become apparent by reference to the following detailed specification and drawings of a specific embodiment thereof, wherein:

FIG. 1 is a perspective view of one embodiment of the invention;

FIG. 2 is a sectional view taken along the lines 2—2 of FIG. 1;

FIG. 3 is a sectional view taken along the lines 3—3 of FIG. 2;

FIG. 4 is a sectional view taken along the lines 4—4 of FIG. 3;

FIG. 5 is a schematic plan view showing the flow of cooling fluid through the system illustrated in FIG. 1;

FIG. 6 is an exploded view of an electronic circuit unit for use in the embodiment of FIG. 1; and

FIG. 7 is a partial cross-sectional view of an electronic circuit unit including a discrete component, such as a resistor, affixed to one side of the unit in which the leads of the components are coupled to the opposite side of the unit.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates, in perspective, a modular electronic system **10** constructed in accordance with the teachings of this invention. The system **10** includes a plurality of stacked electronic units **11—11**, one of the units **11** being shown partially removed from the stack to provide for a better understanding of the invention. An optional, enclosing cover **12** is shown partly broken away and exploded away from the unit **10** to provide for a better pictorial representation of the view. The cover **12** is not necessary for an understanding of the invention.



A front mounting plate **13** has an orifice **14** for an air inlet therethrough for providing a coolant fluid through to the system **10**. The coolant fluid may be air or other suitable medium. The front mounting plate **13** includes various electrical connectors **16—16** for mating with electrical cables (not shown) for connection to other electrical apparatus (not shown). A rear mounting plate **18** is provided at the opposite end of the system **10**. Clamping arms **19—19**, at both the upper left and upper right of the system **10**, are pivotally connected to the rear mounting plate **18**, and are adapted to engage with the front mounting plate **13** so as to clamp the rear mounting plate **18**, all of the electronic units **11—11**, and the front mounting plate **13** together in a stacked arrangement. The clamping arms hold the units **11—11** together from front to back. They do not press the units **11—11** down as such. The units **11—11** form an integral part of a boxlike structure so that vibration is kept to a minimum.

FIG. 2 shows a sectional view of an electronic unit **11** taken along the lines 2—2 of FIG. 1. FIG. 6 illustrates an exploded view thereof. The electronic unit **11** includes a hollow, heat conductive frame **20** constructed of suitable heat conductive material, such as aluminum. The hollow frame **20** is generally rectangular in shape and is provided with cutaway notches **21—21** at its four corners so as to receive the two upper clamping arms **19—19** and lower guide rods (not shown). The hollow frame **20** is formed with a left border member **22**, a top border member **23**, a right border member **24**, and a lower border member **25**. The left border member **22** has an elongated aperture **27** formed therein and therealong from one side of the frame **20** to the opposite side thereof. Similarly, the right border member **24** contains an elongated aperture **28** therethrough and therealong from one side of the frame **20** to the opposite side thereof.

A slot **29** joins the aperture **27** to the interior or hollow portion of the frame **20**. The slot **29** may be constructed of two distinct slot portions ***29a*, *29b*** between the aperture **27** and the hollow portion of the frame **20**. The slot portions ***29a*, *29b*** can be separated by a structural member **31** which joins the left border member **22** to the right border member **24**. In similar fashion, slot portions ***32a*, *32b*** join the hollow portion of the frame **20** to the aperture **28** of the right border member **24**.

Most of the units **11—11** include the structural member **31**, or central spacer from one side to the other to provide support. The width of the member **31** can vary, depending upon the amount of air in which is desired to flow through the unit **11** to provide for optimum heat dissipation therethrough.

The electronic unit **11** includes the hollow heat conductive frame **20** as its basic structural member. In addition, the unit **11** includes a pair of laminates **36, 43** (FIG. **6**), one affixed to each side of the frame **20**. The laminate **36** includes a first, substantially rectangular printed circuit board **33**, having components **34—34** disposed thereon, and a first, similarly shaped rectangular thin sheet **35** of heat conductive metal, such as copper. Electrical insulating means **37** are provided for laminating the printed circuit board **33** to the metal sheet **35**. In a similar fashion, a second printer circuit board **39**, a metal sheet **41**, and electrical insulating means **42** are laminated together to form the laminate **43**. The laminates **36** and **43** are affixed to each side of the heat conductive frame **20** by means of adhesive **44**.

When the laminates **36** and **43** affixed to both sides of the hollow frame **20**, suitable electrical connections are provided for coupling the printed circuit boards **33** and **39** through the lower border member **25** of the frame **20**, in a manner depicted in FIG. 2.

FIG. 2 further illustrates the electronic unit **11** inserted into an electrical connection medium, such as a motherboard **50**, through the use of male electrical contacts **51—51**.

The male electrical contacts **51—51** of the printed circuit boards **33, 39** fit within corresponding female electrical contacts of the motherboard **50**. Each male electrical contact **51** has a width substantially greater than its thickness. The contacts 51—51 are so oriented with their widths perpendicular to the surface of the printed circuit boards 33, 39. The mating female electrical contacts of the motherboard 50 are tight fitting with respect to thickness and loose fitting with respect to width, so that the electronic units 11—11 can be slightly moved in a directing towards or away from the front of the system 10 as shown in FIG. 1. The contacts 51—51 of the printed circuit boards 33, 39 are oriented perpendicular to the surfaces thereof so that when they are fed into the motherboard 50, they may move longitudinally to permit for some movement with respect to the motherboard due to tolerance accumulations. Hence, by putting in a number of units 11 (e.g., eight units) into a motherboard, due to tolerance accumulations, the boards 33, 39 may still properly mate within the motherboard 50 due to the extra width of the female contacts of the motherboard with respect to the individual contacts 51—51 of the printed circuit boards.

FIG. 3 illustrates a sectional view taken along the lines 3—3 of FIG. 2, wherein the motherboard 50 is coupled to a second motherboard 52 by means of flexible wiring tape 53. The flexible wiring tape 53 fits within a concavity of a dummy electronic unit 54. A dummy unit 54 is inserted between each functional set of units 11. This dummy unit 54 would reside between two adjacent motherboards 50, 52 which are connected to each other by the flexible printed wiring tape 53, the length of the flexible printed wiring tape being somewhat in excess of the width of the dummy unit 54. The flexible tape 53 is of sufficient length to form a loop within the concavity, so that, due to tolerance limitations and errors that may occur, close compacting of the electronic units 11—11 can occur without physically damaging the contacts 51—51 or the motherboards 50, 52.

Referring to FIGS. 3 and 4, the motherboard 50 (and, similarly, the motherboard 52) is constructed physically of two portions: an epoxy circuit board portion 50*a* and a rigid female connector plate 50*b*. Thus, the male contacts 51—51 from the electronic units 11—11 fit within the female connector plate 50*b*, the connector plate 50*b* providing contacts then directly to the epoxy circuit board 50*a*. The epoxy circuit board 50*a* and the connector plate 50*b* act as a motherboard 50 and, by the nature of its construction, combines the versatility of printed circuitry, via the epoxy circuit board 50*a*, together with the structural advantages that a rigid connector plate 50*b* offers. One advantage of using flexible wiring tape 53, such as polyethylene terephthalate tape (such tape being available under the trademark name Mylar) is to take care of a situation wherein each of the units 11 is not precisely to size. The units 11 may vary in tolerance so that if the units 11—11 are slightly oversized or slightly undersized, improper fitting might occur. However, by using flexible printed wiring, the motherboards 50, 52 permitted to float, all the units 11—11 can fit without jamming, and the units 11—11 properly mate with the motherboards 50, 52.

As illustrated in FIG. 6, the electronic unit 11 may house components 34—34, which components 34, typically, may be flat packs and other miniaturized circuits including beam lead integrated circuits and the like, which can be affixed directly to the printed circuitry of the printed circuit board 33. As an alternative, or in addition if it is so desired, discrete larger components, such as a resistor 61, as shown in FIG. 7, can be held against the surface of the printed circuit board 39, with its leads 62 going through the laminate 43, the hollow spacing or chamber within the unit 11, through the laminate 36, and affixed to the circuitry of the printed circuit board 33. In such a case, it is desired that the leads 62 of the resistor 61 be enclosed within the spacing between the two laminates 43, 36 by an insulating epoxy button 63. As a feature, the electronic unit 11, when holding discrete components, such as resistors 61 may have the epoxy button 63 placed within the air spacing between the two opposed laminates 36, 43 which is cemented in place with epoxy. Then, a hole is drilled through the two laminates 36, 43 through the epoxy button 63 so that the resistor 61 wire lead can be fed through the epoxy button 63. The button 63 isolates the resistor 61 from the coolant fluid that is to be passed between the spacings of the electronic units 11—11. The button 63, or equivalent, is necessary for certain government requirements and is highly desired from a safety viewpoint in that, one, a fire hazard is eliminated and, two, air leakage through the resistor hole is inhibited.

FIG. 5 is a schematic plan view showing the flow of cooling fluid through the system 10, wherein cooling fluid can be passed through the intake orifice 14 of the front mounting plate 13, and passed through a plenum 66 formed by the elongated apertures 28 of each of the electronic units 11—11. The cooling fluid then passes from the plenum 66, in parallel, through all the slot portions 32*a*, 32*b* of the electronic units 11—11, through the hollow spacings 67—67 within the units 11—11, and out through all the slot portions 29*a* 29*b* thereof to the cavity 68 formed by all of the elongated apertures 27 of the electronic units 11—11. Cooling fluid, then, passes therefrom through an exiting orifice 69 in the rear mounting plate 18. Thus, as illustrated in FIG. 5, air flows in directly through the front of the system 10, into the plenum 66, in parallel through all the spaces 67—67 within the units 11—11, through the cavity 68, and then out through the exiting orifice to the rear of the system 10.

## IN GENERAL

With the rigid construction provided, the modular electronic system 10 is able to withstand high vibrations, high shock, and high "*g*" accellerations making it highly suitable for use in aircraft and spacecraft. Due to its construction, it is inherently a rigid low vibration transmissibility structure.

By using a parallel air pressure system through the spacings 67—67 within the units 11—11, there is a low pressure drop from the input air to the output air, thereby maintaining the input airflow rate. A high pressure input air source, thus, is not required. Comparatively, serial configurations of the prior art would, typically, require 4 inches of water drop pressure, whereby in the novel embodiment described, only one inch of water pressure drop is required. Air is fed through the front of the system 10, through the plenum 66 at the right of the electronic units 11—11. All the units 11—11 are cramped closely together so that a single plenum 66 is formed. The air then passes through the internal spacings 67 of the units 11—11 into the left cavity 68 which is formed by the apertures 27—27 and out through the outlet 69 at the rear of the system 10.

The overall modular system 10 can be made expandable because of the independent front mounting plate 13 and the independent rear mounting plate 18, so that if it is desired to add additional electronic units 11—11, the rear plate 18 can be extended so that additional units 11—11 can be inserted therein. The two clamping arms 19—19 can be replaced by larger or longer arms.

This invention is applicable to almost any kind of electronic system, such as television, radar, computers, and the like, with especial emphasis on large industrial or government systems. For example, in a data processing system, a plurality of cards can form an input-output unit, a processing unit, a memory, a power supply, and a voltage regulator. It is desirable that these "blocks" be modular and removable and functionally independent of each other. It is desired that an interconnection system be associated with each of the "blocks."

The metal sheets 35, 41, in the preferred embodiment, are copper, although aluminum or another suitable conductive metal may be used. Copper is preferred because it is easy to manufacture. A copper interface between the components and the air acts as a thermal diffuser to spread heat concentrations. It decreases the heat density over a large surface of the copper sheet. The frames 20, are, preferably, hard anodized aluminum. There is some, but very little, heat dissipation through the frame 20. This is advantageous because if an air supply is temporarily terminated, then there is some heat dissipated through the frame 20 of the individual units 11—11, and, in case of catastrophic failure of the air flow, heat can still be dissipated for a short period of time. This would find advantage in missile applications or space applications where airflow may be temporarily disrupted for 15 or 20 minutes. During this temporary period, in missile or space flight, the heat could be dissipated through the outside of the aircraft. This would be somewhat similar to prior art systems wherein heat would be dissipated continuously in this manner; however, with this invention, heat would be removed only temporarily during that interval of failure.

## CONCLUSION

Various modifications will suggest themselves to those skilled in the art, without departing from the spirit and scope of this invention. For example, each individual frame **20** can be provided with gaskets about the large apertures **27, 28** to prevent leakage of air. In addition, this design is adaptable for continuous heat dissipation by thermal conduction by including an additional plate through which a cooling fluid passes. Sandwiched between this plate and the irregular surface formed by the plurality of frames **20** would be a thin flexible sheet, made from a good thermally conductive material, which would permit sufficient thermal conduction between the irregular surface and the additional plate. Therefore heat is removed from the system by thermal conduction from the copper sheets, e.g., **35** and **41**, through the frame **20**, through the sheet of conductive material to the external cold plate the temperature of which is maintained at some approximately low level by the cooling fluid.

We claim:

1. A modular electronic system comprising

A. a plurality of stacked electronic circuit units having a first cavity through the stack along one edge thereof, and a second cavity through the stack along an opposite edge thereof, each of said units having a chamber joining said first cavity to said second cavity, each of said units including, a first insulated printed circuit board having components thereon and a first sheet of heat conductive material forming together a first laminate, a second insulated printed circuit board having components thereon and a second sheet of heat conductive material forming together a second laminate, and a frame holding said first laminate on one side thereof and holding said second laminate on the opposite side thereof forming said chamber therebetween, said frame having a pair of slots connecting said chamber to said first cavity and to said second cavity,

B. a first mounting plate having an orifice therethrough communicating with said first cavity,

C. a second mounting plate having an orifice therethrough communicating with said second cavity, and

D. means clamping said first mounting plate, said stacked units, and said second mounting plate together forming a continuous passageway through

1. said first mounting plate orifice, through
2. said first cavity, through, in parallel,
   a. all of said chambers, through
3. said second cavity, and exiting through
4. said second mounting plate orifice.

2. A modular electronic system comprising:

A. a plurality of stacked electronic circuit units, each of said units including

1. a first, substantially rectangular, printed circuit board having components thereon,
2. a first, substantially rectangular, thin sheet of heat conductive material,
3. insulating means for laminating said first printed circuit board to said first sheet, thus forming a first laminate,
4. a second, substantially rectangular printed circuit board having components thereon,
5. a second, substantially rectangular, thin sheet of heat conductive material,
6. insulating means for laminating said second printed circuit board to said second sheet, thus forming a second laminate,
7. a hollow, heat conductive frame holding said first laminate on one side thereof, and holding said second laminate on the opposite side thereof, the sheets of both of said laminates being oriented inwardly with respect to said frame and separated from each other to form a chamber between them, said frame being formed in a generally rectangular configuration having four border members,
   a. one of said border members having a first elongated aperture formed therethrough and therealong from one side of said frame to the opposite side of said frame, and further having a first slot joining said first elongated aperture to said chamber, and
   b. a second of said border members, nonadjacent to said one member, having an elongated aperture—hereinafter termed second elongated aperture—formed therethrough and therealong from one side of said frame to the opposite side of said frame, and further having a slot—hereinafter termed second slot—joining said second elongated aperture to said chamber, and
8. means affixing said laminates to said frame,

B. a front mounting plate, in contact with one end of said stacked electronic units, having an orifice therethrough communicating with the first elongated apertures of said frames,

C. a back mounting plate, in contact with the opposite end of said stacked electronic units, having an orifice therethrough communicating with the second elongated apertures of said frames, and

D. means clamping the front and back mounting plates and the intermediately oriented stacked electronic units forming a continuous passageway through

1. said front mounting plate orifice, through
2. a plenum formed by the stacked first elongated apertures of said circuit units, through, in parallel,
   a. the first slots of all of said frames, then,
   b. said chambers of all of said frames, thereby directly cooling said sheets and indirectly cooling said boards and the components on said boards, and then
   c. the second slots of all said frames,
3. a cavity formed by the stacked second elongated apertures of said circuit units, and exiting through
4. said back mounting plate orifice.

3. The modular electronic system as recited in claim 2 further wherein said printed circuit boards have male electrical contacts disposed along a third of said border members, and further comprising electrical interconnecting means including female electrical contacts mating with said male contacts.

4. The modular electronic system as recited in claim 3 wherein each male electrical contact has a width substantially greater than its thickness, said male contacts being so oriented with their widths perpendicular to the surface of the printed circuit boards, and wherein the mating female electrical contacts are tight fitting with respect to thickness and loose fitting with respect to width.

5. The modular electronic system as recited in claim 4 wherein said electrical interconnecting means comprises

A. a first electrical interconnect board containing female electrical contacts communicating with corresponding male contacts of a first plurality of adjacent stacked electronic circuit units;

B. a second electrical interconnect board containing female electrical contacts communicating with corresponding male contacts of a second plurality of adjacent stacked electronic circuit units; and

C. flexible electrical wiring tape joining said first interconnect board to said second interconnect board, said tape having a length exceeding L +T;

said system further comprising a dummy electronic circuit unit including a plate having a width L having elongated apertures along two opposite borders thereof so as to align, plenum and cavity, with the first and second pluralities of stacked units, said plate having a concavity within a third border thereof so as to receive a loop of said tape therewithin, and

wherein the value T represents the maximum dimensional tolerance error in width that can occur by stacking a first plurality of adjacent stacked circuit units together.

6. The modular electronic system as recited in claim 2 further wherein each of said stacked electronic circuit units contains a heat conductive structural member joining one of said border members intermediate said first elongated aperture to the second of said border members intermediate said second elongated aperture forming chamber portions, the width of the various structural members being optimized so as to vary the cross-sectional area of the chamber portions of each unit, so as to optimize the degree of cooling of each circuit unit.

7. The modular electronic system as recited in claim 2 wherein said front mounting plate and said back mounting plate are constructed of heat conductive material.

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