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(54) ACTIVE VENTS FOR COOLING OF COMPUTING DEVICE

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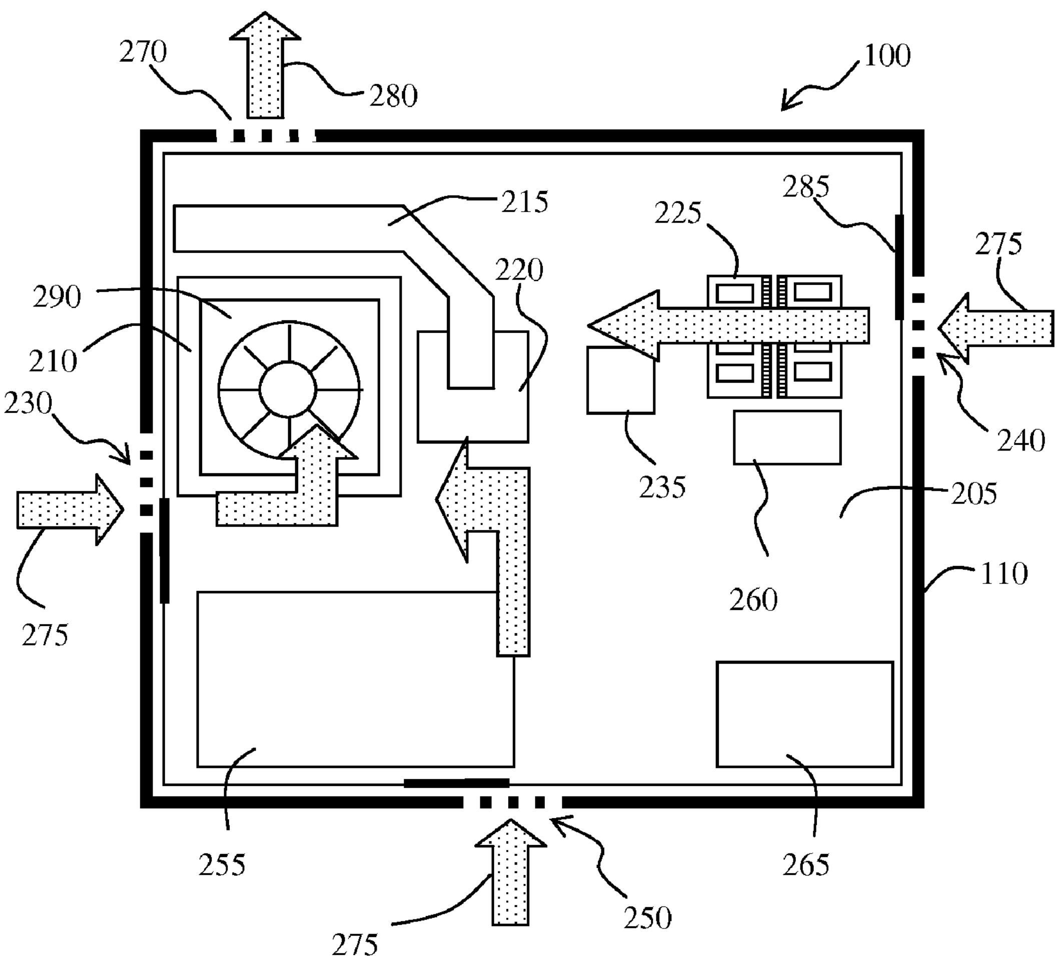
(57) ABSTRACT

Apparatus and methods of cooling a computing device using active air vents. Embodiments include active air vents capable of dynamically changing the pattern of inlet airflow into the housing of the computing device and selectively directing airflow to cool heat-generating components on need basis. Embodiments include active vents coupled to an actuation mechanism to preferentially open and close the active air vents so that inlet airflow into the housing can be regulated based on the cooling requirement of heat-generating components in the housing. Embodiments also include a control module to determine the cooling requirement of the components of the device.



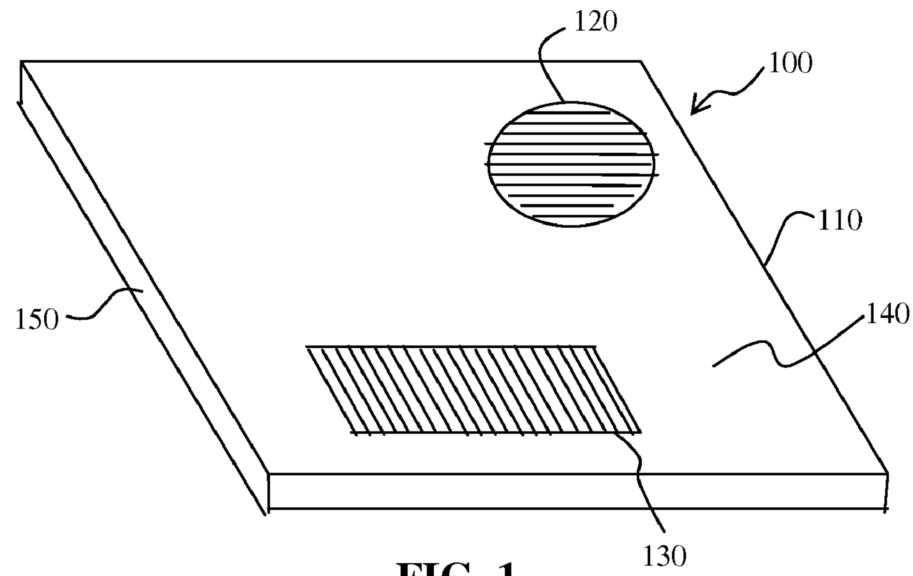

120
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FIG. 1

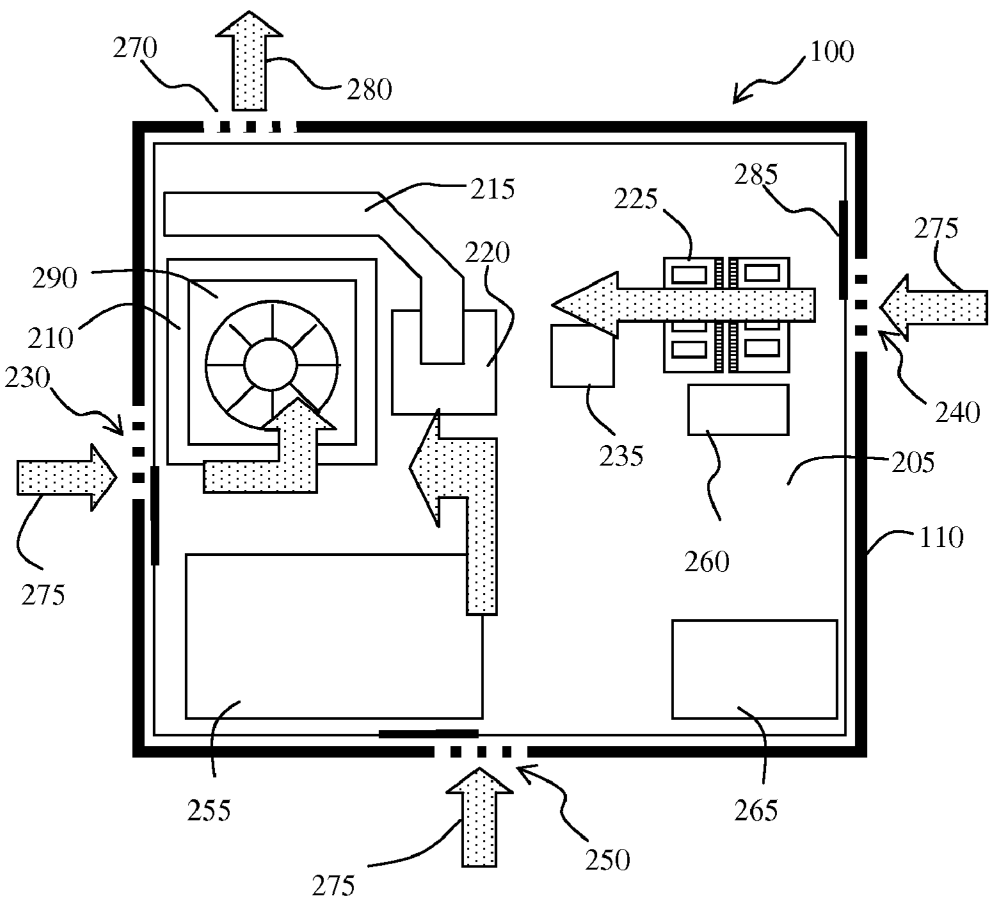
270
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FIG. 2

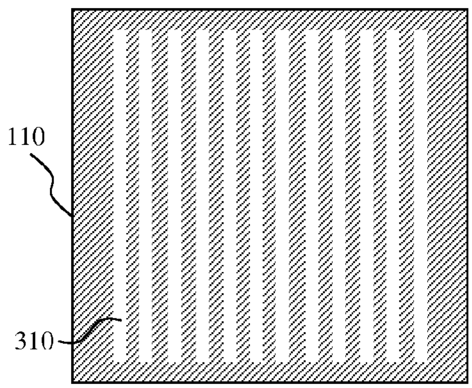

FIG. 3

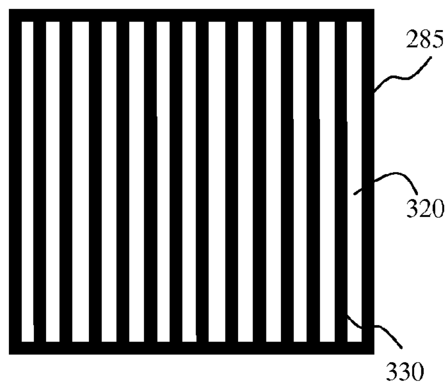

FIG. 4

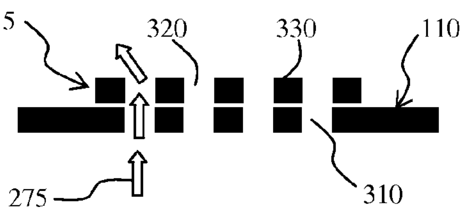

FIG. 5

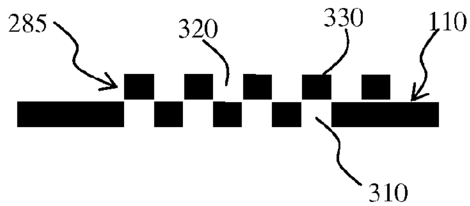

FIG. 6

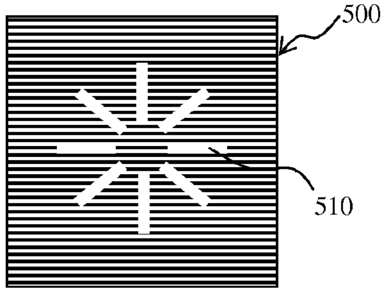

FIG. 7

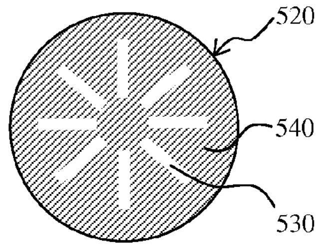

FIG. 8

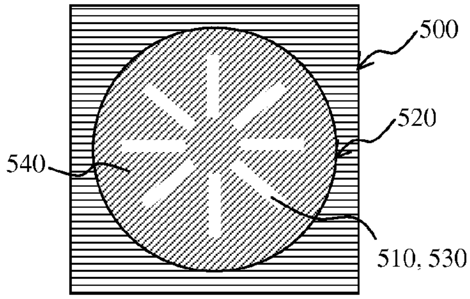

FIG. 9

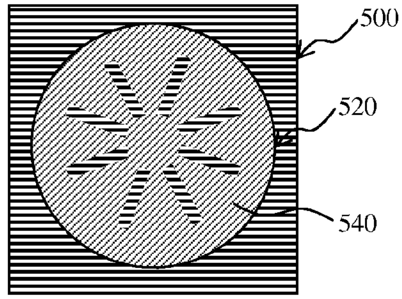

FIG. 10

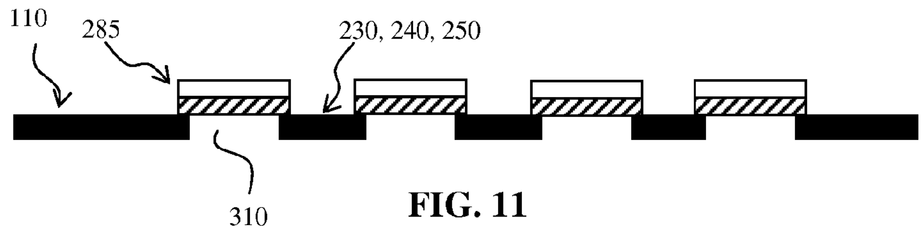

FIG. 11

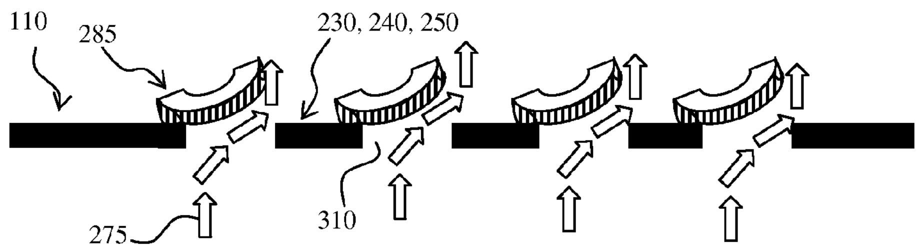

FIG. 12

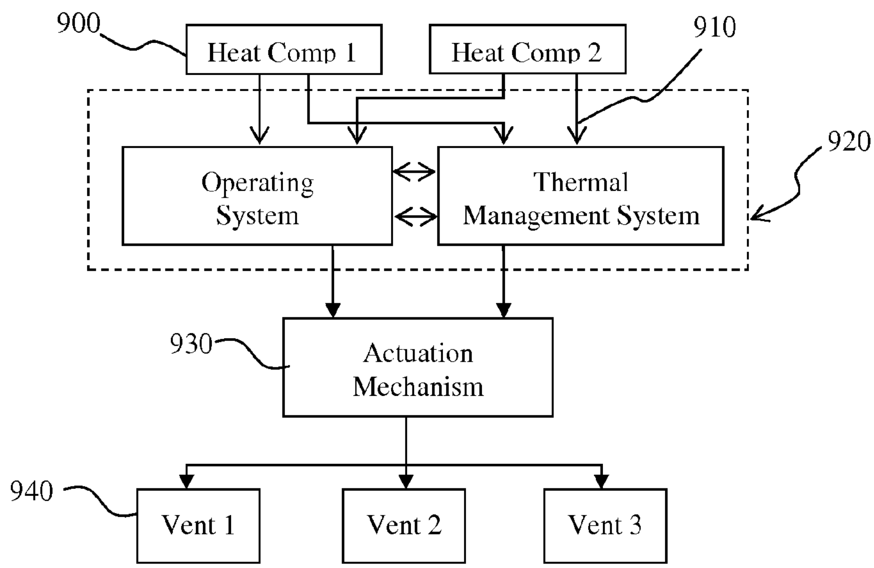

FIG. 13

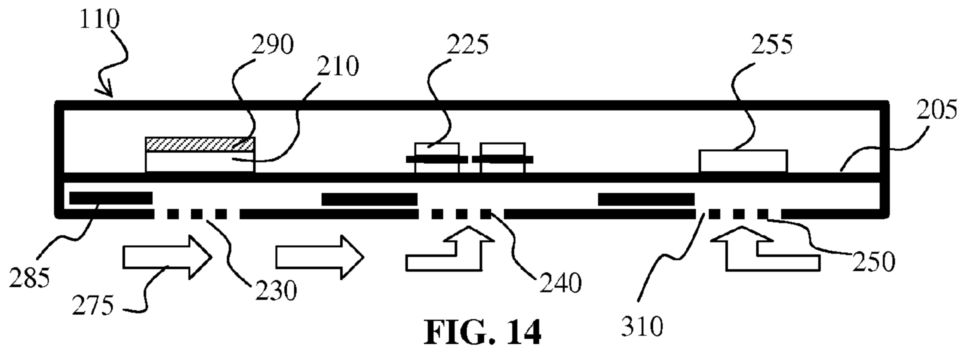

FIG. 14

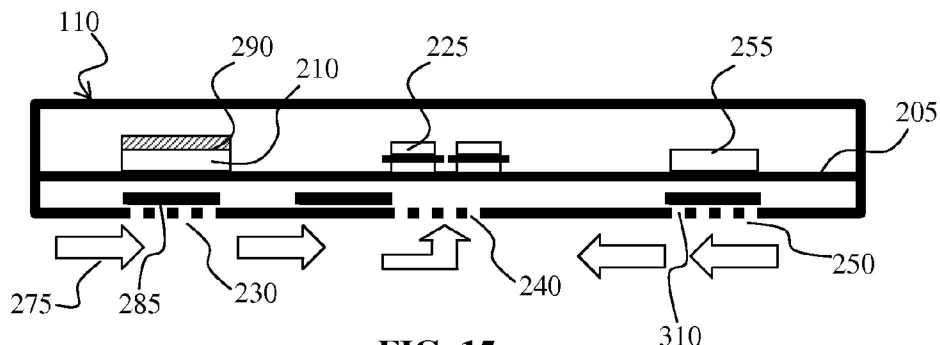

FIG. 15

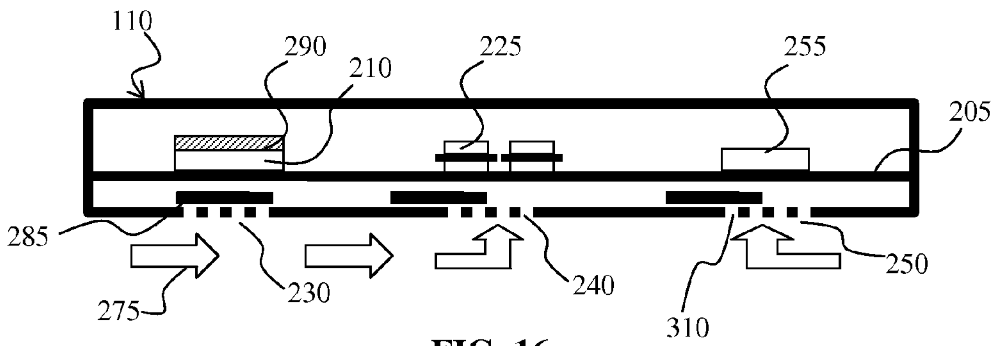

FIG. 16

ACTIVE VENTS FOR COOLING OF COMPUTING DEVICE

FIELD

[0001] Embodiments of the present invention relate to cooling of computing devices. More particularly, embodiments relate to active vents for cooling of computing devices.

BACKGROUND

[0002] Mobile computing devices such as laptop computers, nettops, mobile internet devices (MID), personal digital assistant (PDA) and smartphones are popular among consumers who demand mobile computing and internet connectivity. These devices are designed with ever powerful electronic components within a smaller and slimmer casing to appeal consumers. On the other hand, electronic components generate heat and need to be cooled so that the device can operate at optimum temperature range. Efficient cooling is even more critical for mobile computing devices to avoid a user from feeling the uncomfortable heat from the device casing during physical contact with the devices.

[0003] Computing devices such as laptop computers utilize a cooling fan and/or a heat sink to cool electronic components within the casing with air. Cooling fan assists air ventilation by creating a negative pressure gradient in the casing relative to the ambient. The casing generally has multiple air vents to allow ambient cool air being drawn into the casing to cool the electronic components as well as to allow hot air to leave the casing. Air vents are designed at strategic locations on the casing where adjacent electronic components are expected to generate significant heat and require cooling. Typically, these air vents remain always open to entrain ambient air regardless whether the adjacent electronic components require cooling.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Embodiments of the invention are illustrated by way of example and not limited in the figures of the accompanying drawings, in which like references indicate similar elements.

[0005] FIG. **1** is a perspective view of the bottom side of an embodiment of a computing device;

[0006] FIG. **2** is a cut plane showing the inside of a computing device according to an embodiment;

[0007] FIG. **3** is a top view of an inlet air vent according to an embodiment;

[0008] FIG. **4** is a top view of a cover member according to an embodiment;

[0009] FIG. **5** and FIG. **6** are side views of a cover member aligned to an inlet air vent according to an embodiment;

[0010] FIG. **7** is a top view of an inlet air vent according to another embodiment;

[0011] FIG. **8** is a top view of a cover member according to another embodiment;

[0012] FIG. **9** and FIG. **10** are top views of a cover member aligned to an inlet air vent according to another embodiment;

[0013] FIG. **11** and FIG. **12** are side views of a passive actuation mechanism to regulate inlet airflow into a housing of a computing device according to an embodiment;

[0014] FIG. **13** is a block diagram of a computing device cooling system based on active air vents according to an embodiment;

[0015] FIGS. **14-16** are side views of active air vents selectively directing inlet airflow into a housing of a computing device according to an embodiment;

DETAILED DESCRIPTION

[0016] Embodiments of the present invention are directed to an apparatus and a method of cooling a computing device. Embodiments include a device housing having active air vents to entrain inlet air from the ambient into the housing. The air vents are active in that cover members paired to the air vents preferentially open and close the air vents to regulate the inlet airflow into the housing based on the cooling requirement of heat-generating components within the housing. Embodiments include an actuation mechanism to position the cover members relative to the air vents. Embodiments also include a control module to determine the cooling requirement of the components of the device. By controlling the degree of opening of the air vents, the flow pattern of inlet airflow into the housing is dynamically altered. Inlet airflow can therefore be selectively directed to cool the heat-generating components on need basis.

[0017] FIG. **1** is a perspective view of the bottom side of an embodiment of computing device **100**. For an embodiment, computing device **100** is a notebook computer (laptop). However, other electronic devices such as netbooks, personal digital assistants (PDA), smart phones as well as other computing systems such as desktop computers, servers, set-top boxes are not precluded. For an embodiment, computing device **100** includes housing **110**, fan inlet vent **120** and memory inlet vent **130**. For an embodiment, both fan inlet vent **120** and memory inlet vent **130** are formed at the bottom skin **140** of housing **110**. Inlet vents **120**, **130** can also be formed at locations on housing **110** other than that depicted in FIG. **1**, for example on the sides **150** of housing **110**. For another embodiment, computing device **100** includes additional air vents for drawing inlet air into housing **110** as well as purging air within housing **110** to the ambient.

[0018] FIG. **2** is a top view of an embodiment of computing device **100**. For an embodiment, computing device **100** is a laptop computer having motherboard **205** disposed within housing **110**. For an embodiment, a plurality of electronic components and semiconductor chips are connected to motherboard **205**. For an embodiment, a first set of heat-generating components is located adjacent to first inlet air vent **230**. For an embodiment, the first set of heat-generating components includes central processing unit (CPU) **210** and graphics memory controller hub (GMCH) **220**. For an embodiment, CPU **210** and GMCH **220** are thermally coupled to heat pipe remote heat exchanger (RHE) **215**. For an embodiment, motherboard **205** includes a second set of heat-generating components such as random access memory (RAM) **225**, wireless LAN card **260** and I/O controller hub (ICH) **235**. The second set of heat-generating components is located adjacent to second inlet air vent **240**. For embodiment, housing **110** also includes third inlet air vent **250** and a third set of heat-generating components is disposed adjacent to inlet air vent **250**. The third set of heat-generating components may include heat-generating parts such as hard drive **255** and power supply unit **265**. Other heat-generating parts such as optical drives, PC cards, and electronic components such as diodes, capacitors and transistors, may be included in either the first, second or third heat-generating components depending on the layout and design of motherboard **205**. For an embodiment, inlet air vents **230**, **240**, **250** are formed as part of housing **110**.

[0019] The term "adjacent" used in the specification denotes proximity. When a component is described to be adjacent to an inlet air vent, it is to be understood that the component is in a location within housing **110** where the inlet airflow from the adjacent inlet air vent is capable of removing heat generated by the component and cooling the component. It is also to be understood that components do not necessarily need to be on the same plane with the adjacent inlet air vent. Components can be disposed above or below the inlet air vent.

[0020] Still referring to FIG. **2**, first inlet air vent **230**, second inlet air vent **240** and third inlet air vent **250** are on different sides of housing **110** according to an embodiment. For another embodiment, inlet air vents **230**, **240**, **250** are not precluded to be formed at other locations of housing **110** such as on bottom skin **140** of housing **110** or having two or more inlet air vents formed on a particular side or on bottom skin **140** of housing **110**. For an embodiment, housing **110** also includes outlet air vent **270** to allow hot air within housing **110** to escape to the ambient. For an embodiment, fan **290** is disposed on CPU **210** to dissipate away heat generated by CPU **210**. Fan **290** also creates a negative pressure gradient within housing **110** relative to the ambient so that cool inlet air **275** is drawn into housing **110** via inlet air vents **230**, **240**, **250** and hot outlet air **280** is purged from housing **110** via outlet air vent **270** according to an embodiment.

[0021] For an embodiment, inlet air vents **230**, **240**, **250** each includes a plurality of through openings and is paired to respective cover members **285**. Inlet air vents **230**, **240**, **250**, together with respective cover members **285**, regulate inlet airflow **275** into housing **110**. It is to be understood that pairing of air vents **230**, **240**, **250** with respective cover members **285** includes but is not limited to positioning cover members **285** adjacent to the respective air vents **230**, **240**, **250** such that the extent of opening of air vents **230**, **240**, **250** not covered by respective cover member **285** regulates the amount of inlet airflow **275** into housing **110**. For an embodiment, cover members **285** are mechanically coupled with respective air vents **230**, **240**, **250**. For another embodiment, cover members **285** are not mechanically coupled to respective air vents **230**, **240**, **250**.

[0022] There are different mechanisms through which cover members **285** paired to respective air vents **230**, **240**, **250** can regulate the inlet airflow **275** into housing **110**. For an embodiment, cover members **285** can slide against and relative to the respective air vents **230**, **240**, **250**. FIG. **3** is a top view of an air vent **230**, **240**, **250** according to an embodiment. For an embodiment, air vents **230**, **240**, **250** each includes a plurality of through openings **310**. For an embodiment, air vents **230**, **240**, **250** have common design and dimensions. However, for other embodiments, air vents **230**, **240**, **250** are not precluded from having different designs or dimensions. For an embodiment, air vents **230**, **240**, **250** are fabricated as part of housing **110**. For another embodiment, air vents **230**, **240**, **250** are assembled with housing **110** and are detachable from housing **110**. For other embodiments, through openings **310** can have different geometrical shapes and configurations. FIG. **4** is a top view of cover member **285** according to an embodiment. For an embodiment, cover member **285** includes a plurality of through openings **320** defined by a plurality of partition members **330**. For an embodiment, the shape, dimension and number of partition members **330** of cover members **285** match through openings **310** of respective air vents **230**, **240**, **250** of which cover members **285** are paired to.

[0023] Turning now to FIG. **5**, FIG. **5** is a side view of cover member **285** paired to an air vent **230**, **240**, **250** according to an embodiment. For an embodiment, cover member **285** is positioned relative to respective air vent **230**, **240**, **250** such that through openings **320** of cover member **285** are aligned with through openings **310** of respective air vents **230**, **240**, **250** to form a plurality of through passages. Such alignment allows maximum inlet airflow **275** through air vents **230**, **240**, **250** into housing **110**. FIG. **6** is a side view of another position of cover member **285** relative to air vent **230**, **240**, **250** according to an embodiment of the invention. For an embodiment, partition members **330** of cover members **285** are aligned against through openings **310** of air vents **230**, **240**, **250** such that partition members **330** completely shut through openings **310**. Such configuration completely obstructs inlet airflow from passing through air vents **230**, **240**, **250** and entering housing **110**. Partial inlet airflow into housing **110** can be obtained by aligning partition members **330** against through openings **310** such that air vents **230**, **240**, **250** are partially open. For another embodiment, cover member **285** can be any structure capable of shutting through openings **310** of air vents **230**, **240**, **250**. For an embodiment, cover member **285** does not have through openings **320** and is a structure with a planar surface. For various embodiments, cover members **285** can be positioned relative to respective air vents **230**, **240**, **250** to vary the size of through openings **310** of air vents **230**, **240**, **250** through which inlet airflow **275** can pass. As such, the amount of inlet airflow **275** passing through air vents **230**, **240**, **250** can be regulated.

[0024] Various embodiments of cover member **285** and inlet air vents **230**, **240**, **250** may exist without departing from the spirit and intent of the invention. Embodiments may include different design, configuration and orientation of cover member **285** with respect to inlet air vents **230**, **240**, **250**. FIG. **7** is a top view of inlet air vent **500** according to an embodiment of the invention. For an embodiment, inlet air vent **500** includes a plurality of through openings **510** arranged in a radial configuration. FIG. **8** is a top view of cover member **520** according to an embodiment and is capable of pairing with inlet air vent **500**. Cover member **520** includes a plurality of through openings **530** defined by planar surface **540**. For an embodiment, the shape, orientation, dimensions and the number of through openings **530** are identical with through openings **510** of inlet air vent **500**. However, through openings **510** of inlet air vent **500** are not precluded from having different shape, orientation, dimensions or count from through openings **530** of cover member **520** for other embodiments. FIG. **9** is a top view of an embodiment of cover member **520** aligned with an embodiment of inlet air vent **500**. Through openings **530** of cover member **520** can be aligned with through openings **510** of inlet air vent **500** to form a through passage between cover member **520** and air vent **500**. The through passage allows inlet airflow **275** from the ambient to enter housing **110**. For an embodiment, cover member **520** can be engagably displaced relative to air vent **500** such that planar surface **540** is either fully or partially covering through openings **510** of air vent **500**. FIG. **10** is a top view of an embodiment of cover member **520** aligned with air vent **500** and completely covering through openings **510** of air vent **500**. For an embodiment, cover member **520**

can be engagably displaced relative to air vent **500** by way of rotating cover member **520**. Other embodiments capable of varying the size of through openings **510** of air vent **500** are also possible.

[0025] Embodiments of the invention include an actuation mechanism configured to engagably displace cover members **285**. For an embodiment, cover members **285** are coupled to an actuation mechanism to regulate the amount of inlet airflow **275** entering housing **110**. For an embodiment, the actuation mechanism actuates cover members **285** relative to respective inlet air vents **230**, **240**, **250** to vary the size of through openings **310**, **510** of inlet air vents **230**, **240**, **250** available for inlet airflow to pass through. For an embodiment, cover members **285** are coupled to a magnetic solenoid system adapted to drive cover members **285** to fully open, fully shut and partially open through openings **310**, **510**. For an embodiment, the magnetic solenoid system includes two sets of magnetic solenoids. For an embodiment, each set of magnetic solenoids includes one or more solenoids. For an embodiment, when a first set of solenoids is actuated, for example when current flows through the windings of the solenoid, cover members **285** are pulled to one side. For an embodiment, through openings **320** of cover members **285** are lined up with through openings **310** of inlet air vents **230**, **240**, **250** (see FIG. **5**). Actuation of a second set of solenoids pulls cover members **285** in an opposite direction such that through openings **310** are closed or partially open. For another embodiment, cover members **285** are coupled to a linear motor to vary the size of through openings **310**, **510**.

[0026] Embodiments of the actuation mechanism to drive the opening and shutting of inlet air vents **230**, **240**, **250** described above include active actuation mechanism. However, embodiments of the invention do not preclude passive actuation mechanism from being adopted to regulate the amount of inlet airflow **275** into housing **110**. For an embodiment, the actuation mechanism to drive cover member **285** to fully shut, fully open and partially open through openings **310** of inlet air vents **230**, **240**, **250** is inherent in cover member **285**. FIG. **11** and FIG. **12** are side views of an embodiment of passive actuation mechanism to regulate inlet airflow **275** into housing **110**. Referring to FIG. **11**, cover members **285** can be aligned to fully shut through openings **310** of inlet air vents **230**, **240**, **250**. For an embodiment, cover members **285** are capable of changing the size and/or shape of cover members **285** as a function of temperature. For example and according to an embodiment, cover members **285** may bend to yield a concave or convex structure when heated. Referring to FIG. **12** and according to an embodiment, cover members **285** bend upwards (away from inlet air vents **230**, **240**, **250**) and cause through openings **310** available for inlet airflow **275** to enter housing **110** via inlet air vents **230**, **240**, **250**. For an embodiment, the degree of curvature of cover member **285** is dependant on the temperature within housing **110**. The higher the temperature within housing **110**, cover members **285** bend to a greater extent and thus allow greater amount of inlet airflow **275** to enter housing **110**. When the temperature within housing **110** drops, cover members **285** bend less and reduce the size of through openings **310** available for inlet airflow **275** to pass through. For an embodiment, cover members **285** is made of shape memory alloy (SMA) materials. Shape memory alloy materials can deform under the excitation of temperature or an electric field but will return to the original shape once the means of excitation is withdrawn. For an embodiment, cover members **285** is a bimetallic strip. Examples of bimetallic strip material may include copper on one part of the strip and aluminum on the other part of the strip or any combination of two metallic materials with different coefficients of thermal expansion.

[0027] Embodiments of the invention include a control module to determine the respective cooling requirement of heat generating components within housing **110**. FIG. **13** is a block diagram of control module **920** to regulate the amount of inlet airflow **275** passing through inlet air vents **230**, **240**, **250**. For an embodiment, control module **920** includes an operating system of computing device **100**. For an embodiment, control module **920** includes a thermal management system. For an embodiment, control module **920** determines cooling requirement **910** of heat-generating components in computing device **100**. For an embodiment, cooling requirement **910** of heat-generating components includes temperature-state inputs, or power-state inputs, or both temperature-state and power-state inputs obtained from heat-generating components. For an embodiment, the temperature or power-state inputs are gathered by way of thermal sensors or thermal diodes sensing the gate or junction temperatures of heat-generating components. For an embodiment, control module **920** also includes an embedded controller having an algorithm executable to alter the Basic Input/Output System (BIOS) of the operating system. For an embodiment, the embedded controller is capable of determining whether cooling of heat-generating components in computing device **100** is required. According to an embodiment, control module **920** controls actuation mechanism **930** based on cooling requirement **910** of heat-generating components. For an embodiment, control module **920** sends signals to actuation mechanism **930** to regulate the amount of inlet airflow **275** via active vents **940**. For an embodiment, actuation mechanism **930** selectively directs inlet airflow **275** into housing **110** via each of active vents based on cooling requirement **910** of heat-generating components.

[0028] When computing device **100** is in operating mode, heat-generating components in housing **110** may require different cooling requirement **910**. For an embodiment, an optimal pattern of inlet airflow **275** entering housing **110** is desired by selectively directing inlet airflow **275** to heat-generating components requiring cooling. FIG. **14** to FIG. **16** are side views of an embodiment selectively directing inlet airflow **275** into housing **110**. Embodiments include motherboard **205** disposed within housing **110**. A plurality of heat-generating components such as CPU **210**, RAM **225** and hard drive **255** are disposed within housing **110**. For an embodiment, CPU **210**, RAM **225** and hard drive **255** are respectively disposed adjacent to first vent **230**, second vent **240** and third air vent **250**. For an embodiment, inlet air vents **230**, **240**, **250** each has a plurality of through openings **310** and is paired with cover member **285**. For an embodiment, cover members **285** are configured to regulate inlet airflow **275** into housing **110** by varying the size of through openings **310** of inlet air vents **230**, **240**, **250**. For an embodiment, cover members **285** are operatively coupled to actuation mechanism **930** configured to cause cover members **285** to fully open, fully shut or partially open through openings **310** of inlet air vents **230**, **240**, **250**. For an embodiment, fan **290** is included in housing **110** to create a negative pressure gradient in housing **110** relative to the ambient. The negative pressure gradient within housing **110** enables an evacuative airflow to flow from the ambient into housing **110**. The evacuative airflow allows cool air from the ambient to replace hot air inside housing **110** and thus cools heat-generating components.

[0029] Referring to FIG. **14**, FIG. **14** is an embodiment having all inlet air vents **230**, **240**, **250** open for inlet airflow **275** to pass through and enter housing **110** to cool heat-generating components. There are scenarios when major components such as CPU **210**, RAM **225** and hard drive **255** are equally stressed and require simultaneous cooling. An example of such scenario is when computing device **100** is running a multi-tasking of applications such as backing up contents of a compact disc (CD) media, 3D gaming and heavy computing load on CPU **210** and RAM **225**. For an embodiment, cooling requirement **910** of each heat-generating component is determined and fed to control module **920**. For an embodiment, control module **920** sends signal to actuation mechanism **930** and causes cover members **285** to fully open through openings **310**. As such, inlet airflows **275** are channeled to cool components requiring cooling.

[0030] Turning now to FIG. **15**, FIG. **15** is an embodiment capable of dynamically changing the pattern of inlet airflow **275** entering housing **110**. There are instances when CPU **210** is running at low power but other components such as RAM **225** and GMCH **220** are running with relatively higher load and thus generate more heat, for example downloading from media-rich contents from the internet. For an embodiment, cooling of CPU **210** and hard drive **255** is not required as much as other components such as RAM **225** and GMCH **220**. As such, higher entrainment of inlet airflow **275** to cool RAM **225** and GMCH **220** is desired. For an embodiment, member covers **285** for first vent **230** and third vent **250** are positioned to fully close through openings **310** and inlet airflow **275** being selectively directed to enter housing **110** via second vent **240** to cool GMCH **225**. In other instances, cover members **285** can be positioned to partially open through openings **310** of air vents based on cooling requirement **910** of particular components. FIG. **16** is an embodiment where cover members **285** of second vent **240** and third vent are kept partially open. Various scenarios concerning different computing load on components of computing device **100** other than those described above may be contemplated. For each scenario, flow pattern of inlet airflow **275** into housing **110** can be dynamically changed to match different cooling requirement of heat-generating components.

[0031] In the foregoing specification, reference has been made to specific embodiments of the invention. It will, however be evident that various modifications and changes may be made thereto without departing from the broader spirit and scope of the invention. The specification and drawings are, accordingly, to be regarded in an illustrative rather than restrictive sense.

What is claimed is:

1. An apparatus, comprising:

a housing of a computing device having at least a first and a second vent, said vents each having a plurality of through openings;

a first set of heat-generating components disposed within the housing and adjacent to the first vent;

a second set of heat-generating components disposed within the housing and adjacent to the second vent;

a plurality of cover members, each being paired to said vents and being configured to regulate airflow into the housing via the through openings of said vents; and

an actuation mechanism being configured to engagably displace the plurality of cover members.

2. The apparatus of claim **1**, further comprising a control module to determine a cooling requirement of the first and second sets of heat-generating components and to control the actuation mechanism based on the cooling requirement.

3. The apparatus of claim **2**, wherein the control module determines the cooling requirement based on temperature-state inputs, or power-state inputs, or a combination of temperature-state and power-state inputs of the first and second heat-generating components.

4. The apparatus of claim **1**, wherein the actuation mechanism includes one of a magnetic solenoid or a linear motor, and is being coupled to the plurality of cover members.

5. The apparatus of claim **4**, wherein each of the plurality of cover members includes a plurality of through openings.

6. The apparatus of claim **1**, wherein the plurality of cover members is capable of varying the size of the through openings of said vents available for inlet airflow to pass.

7. The apparatus of claim **6**, wherein the plurality of cover members is made of shape memory alloy (SMA).

8. The apparatus of claim **6**, wherein the plurality of cover members is a bimetallic strip made of materials with different coefficients of thermal expansion.

9. An assembly, comprising:

a housing of a computing device having at least a first and a second vent, said vents being capable of drawing an inlet airflow through a plurality of through openings of said vents to cool a plurality of heat-generating components disposed within the housing;

a plurality of cover members disposed adjacent to said vents, the cover members being configured to regulate the inlet airflow passing through the through openings;

an actuation mechanism operatively coupled to the plurality of cover members to cause the cover members to fully open, fully shut or partially open said vents; and

a control module operatively connected to an operating system of the computing device and a thermal management system, the control module being configured to determine a cooling requirement for each of the heat-generating components and to activate the actuation mechanism to selectively direct the inlet airflow to cool the heat generating components.

10. The assembly of claim **10**, further comprising a fan adapted to create an evacuative airflow having a negative pressure gradient within the housing relative to the ambient air.

11. The assembly of claim **11**, wherein the control module includes an embedded controller capable of altering the BIOS of the computing device.

12. The assembly of claim **12**, wherein the actuation mechanism includes a magnetic solenoid system or a linear motor.

13. The assembly of claim **10**, wherein the plurality of cover members is capable of varying the size of the through openings of said vents available for inlet airflow to pass.

14. The assembly of claim **14**, wherein the plurality of cover members is made of one of shape memory alloy (SMA) and bimetallic material, wherein the bimetallic material includes materials with different coefficients of thermal expansion.

15. A method, comprising:

disposing at least a first and a second set of heat-generating components in a housing of a computing device, the housing having at least a first vent adjacent to the first set of heat-generating components and a second vent adjacent to the second set of heat-generating components, wherein said vents each includes a plurality of through openings;

determining a cooling requirement for each of the first and second sets of heat-generating components;

causing a plurality of cover members to fully open, fully shut or partially open said vents based on the cooling requirement; and

selectively directing airflow passing through the through openings of said vents to cool the heat-generating components.

16. The method of claim **16**, further comprising aligning a plurality of through openings disposed on the cover members against the through openings of said vents.

17. The method of claim **16**, wherein causing the cover members to fully open, fully shut or partially open said vents includes changing the shape, size or configuration of the cover members.

18. The method of claim **18**, wherein the plurality of cover members is made of shape memory alloy (SMA) or a bimetallic material, wherein the bimetallic material includes materials with different coefficients of thermal expansion.

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