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(54) **POWER MODULE AND APPARATUS**

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(60) Provisional application No. 62/743,251, filed on Oct. 9, 2018, provisional application No. 62/770,432, filed on Nov. 21, 2018.

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H05K 1/11	(2006.01)
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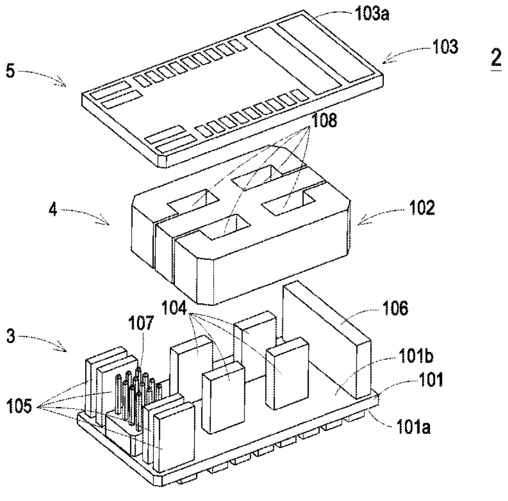
(57) **ABSTRACT**

An apparatus includes a heat-dissipating substrate, a power circuit and a magnetic assembly. The heat-dissipating substrate includes a thermal contact surface. The power circuit includes at least one switch element in contact with the thermal contact surface of the heat-dissipating substrate. The magnetic assembly includes at least one first electrical conductor and a magnetic core module comprising at least one hole, wherein the at least one first electrical conductor passes through the at least one hole, and a terminal of the at least one first electrical conductor is electrically connected to the at least one switch element. The heat-dissipating substrate, the power circuit and the magnetic assembly are arranged in sequence along a same direction. A projection of the power circuit on the thermal contact surface partially overlaps a projection of the magnetic assembly on the thermal contact surface.



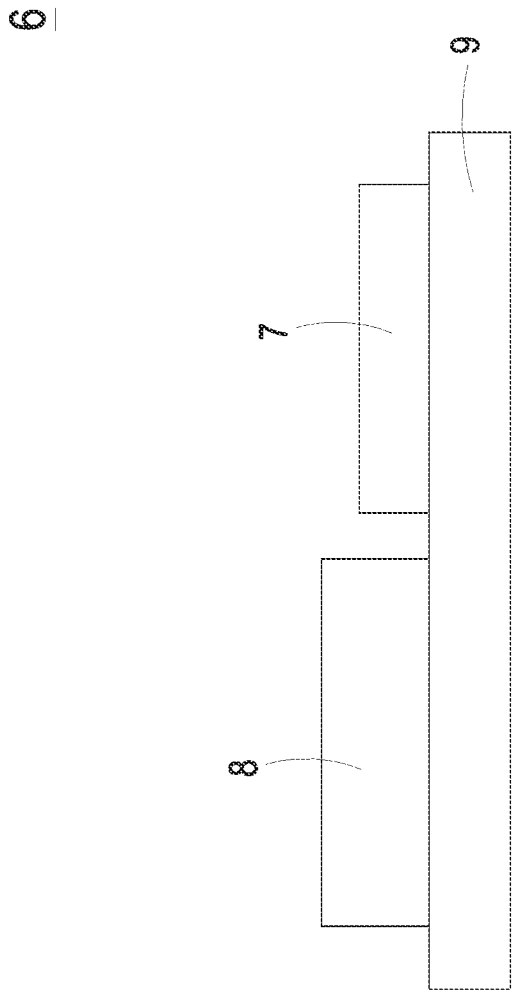


FIG. 1A PRIOR ART

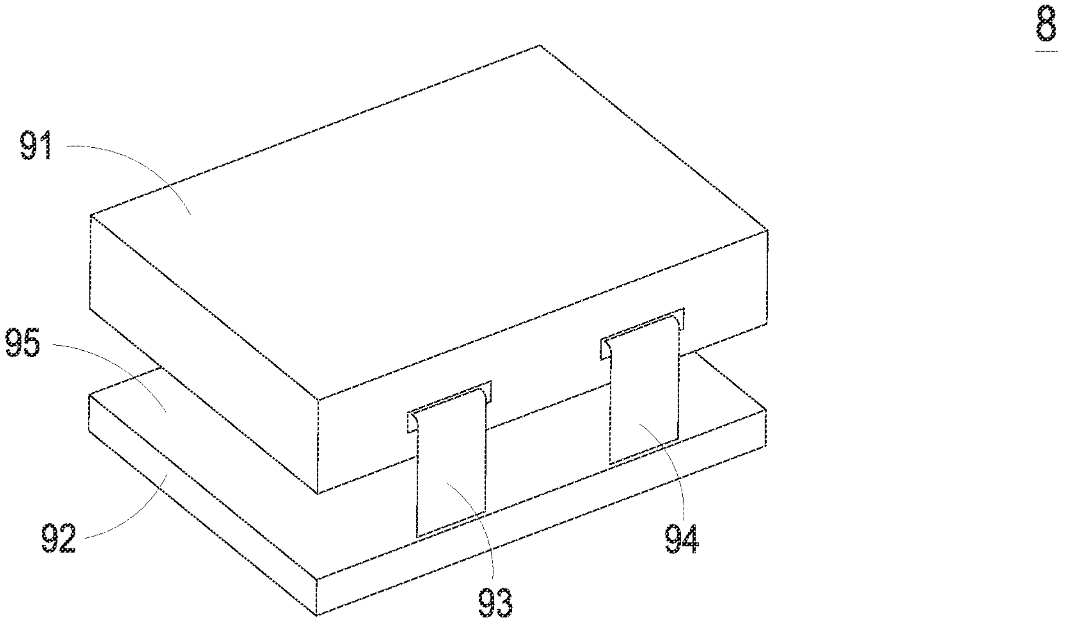


FIG. 1B PRIOR ART

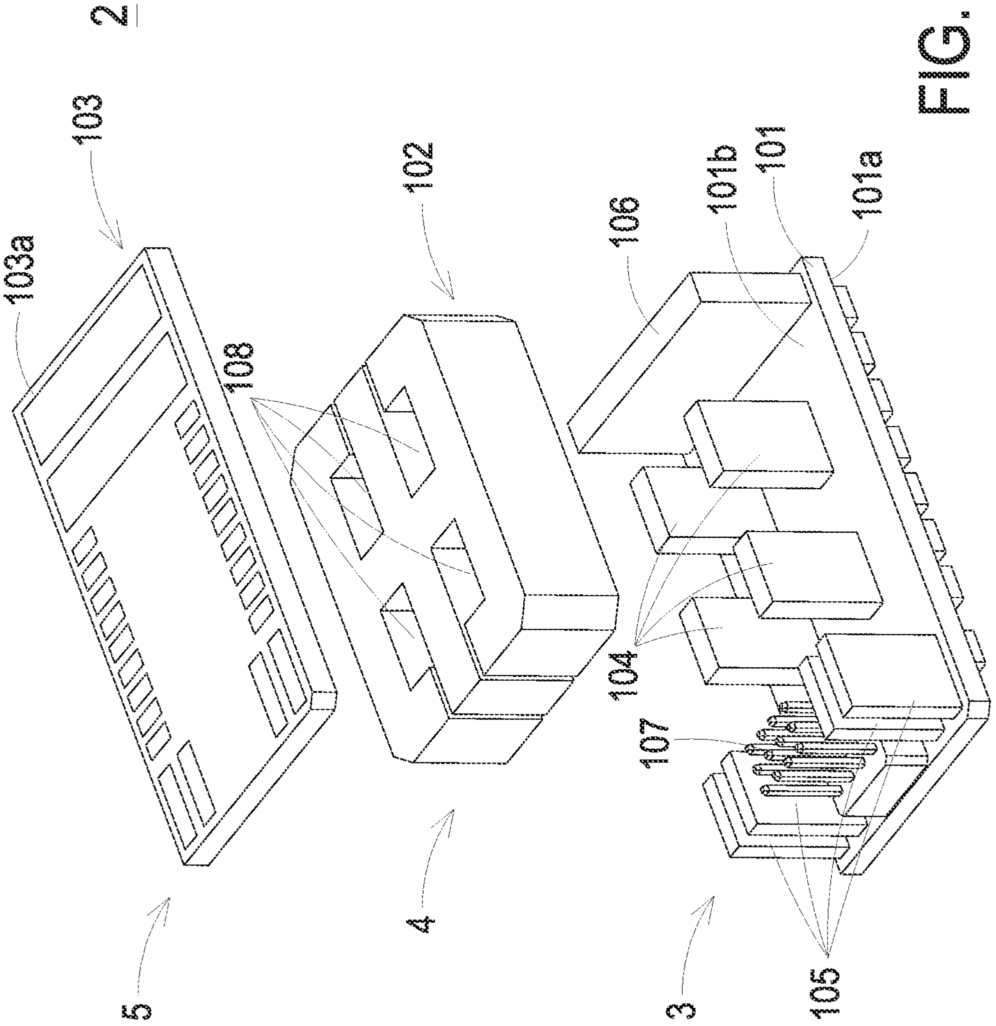


FIG. 2A

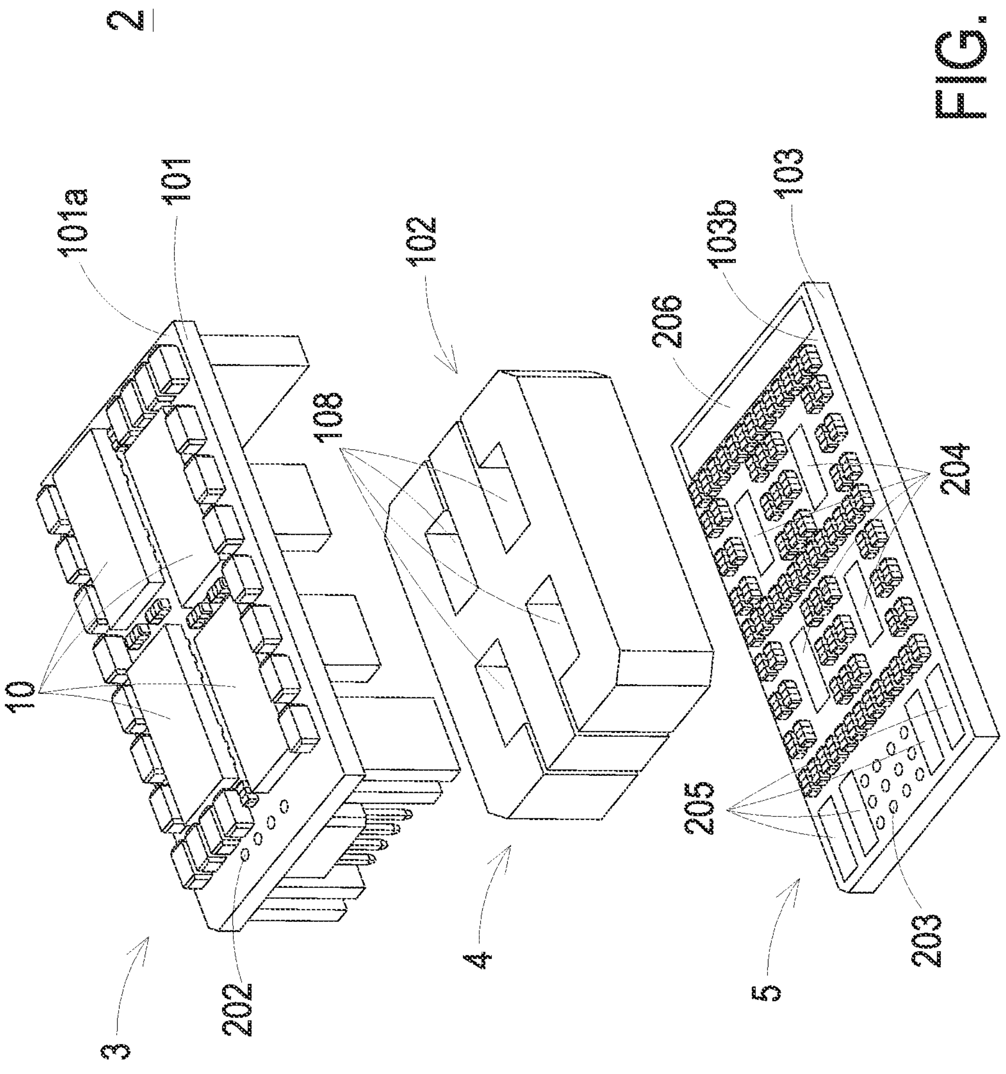


FIG. 2B

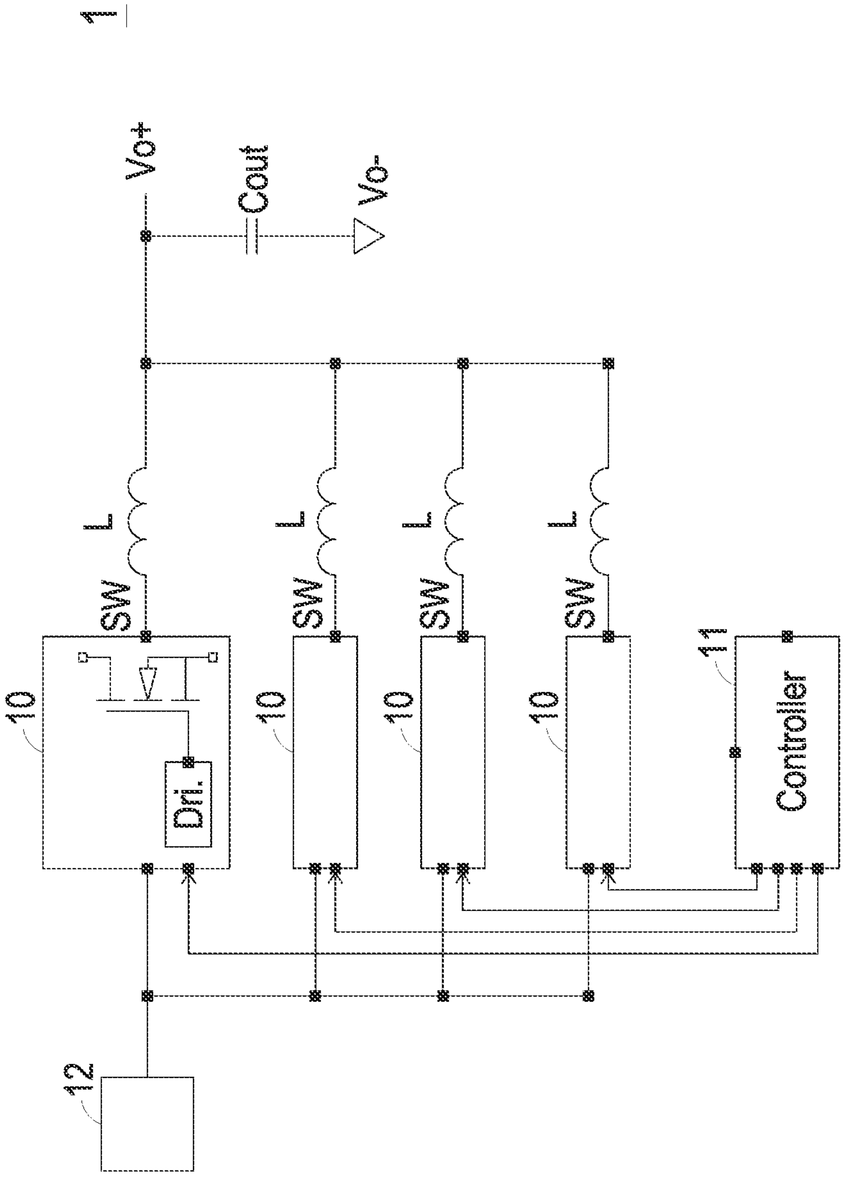


FIG. 3

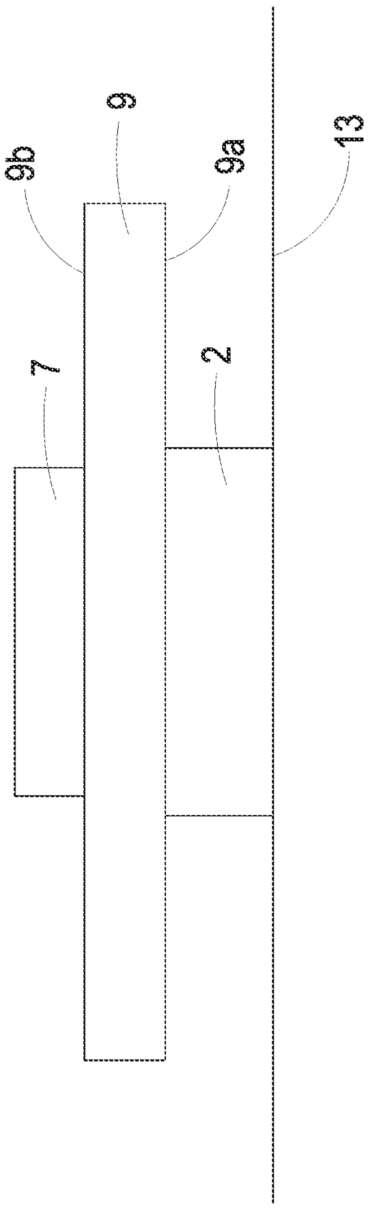


FIG. 4

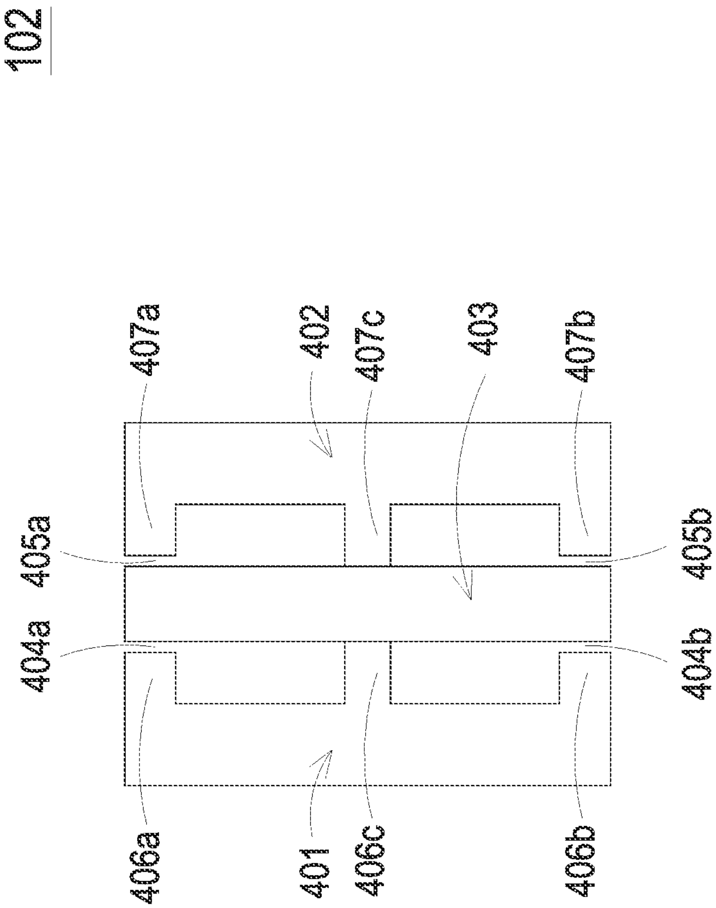

102
407a
402
407c
403
407b
405a
405b
404a
404b
406a
401
406c
406b

FIG. 5

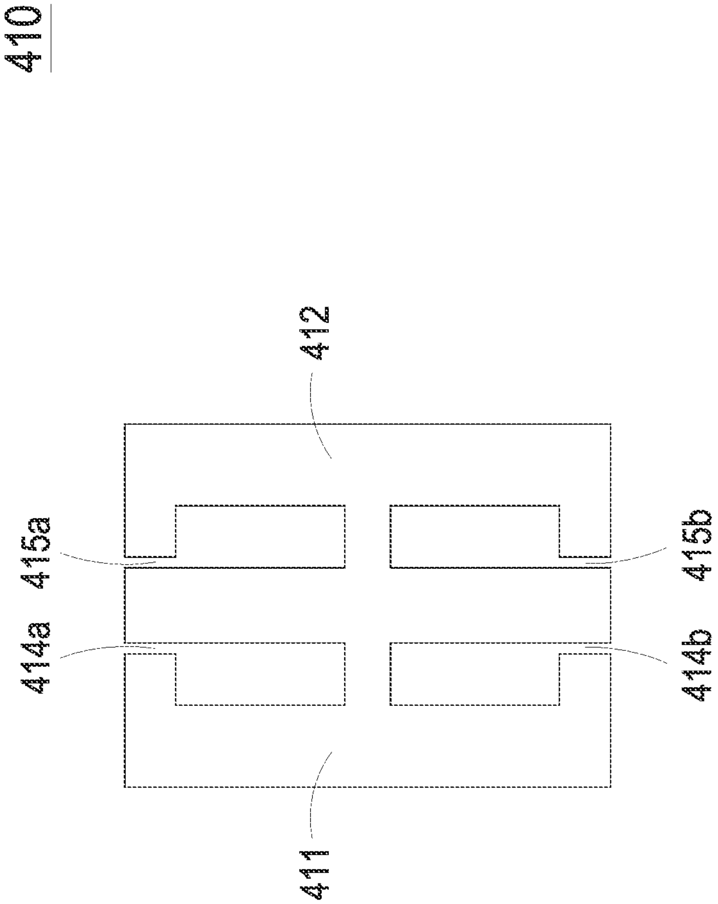


FIG. 6

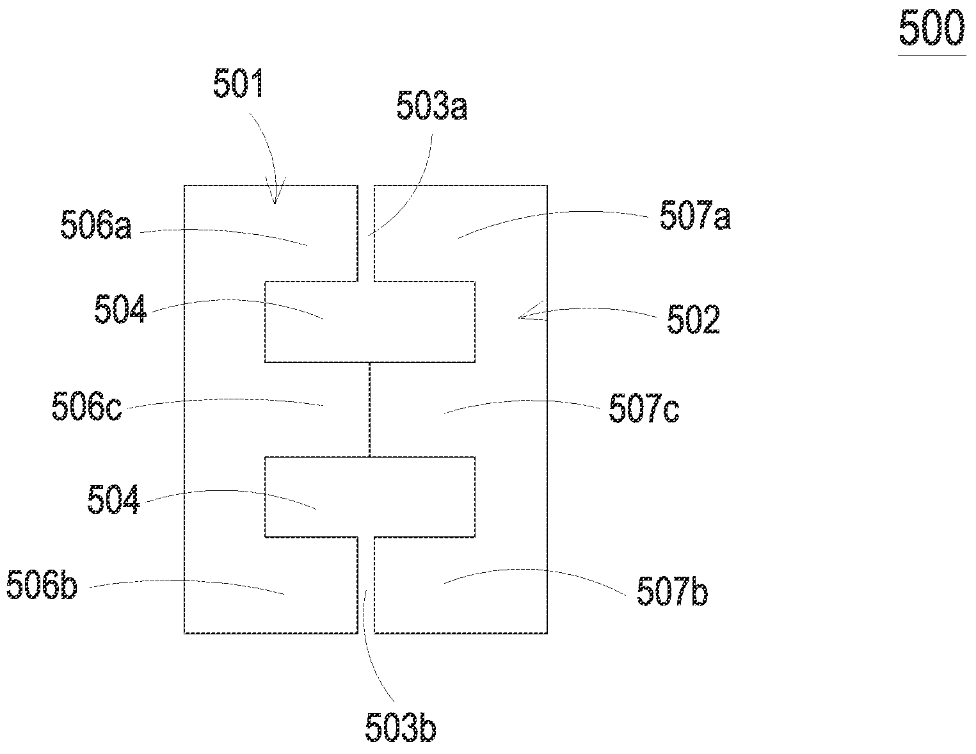


FIG. 7

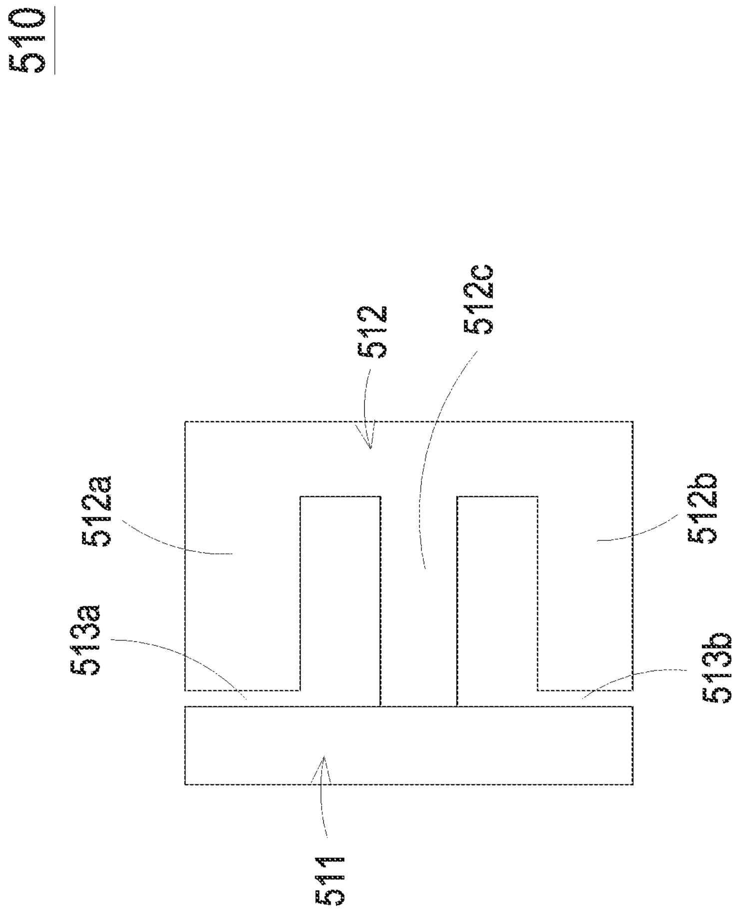


FIG. 8

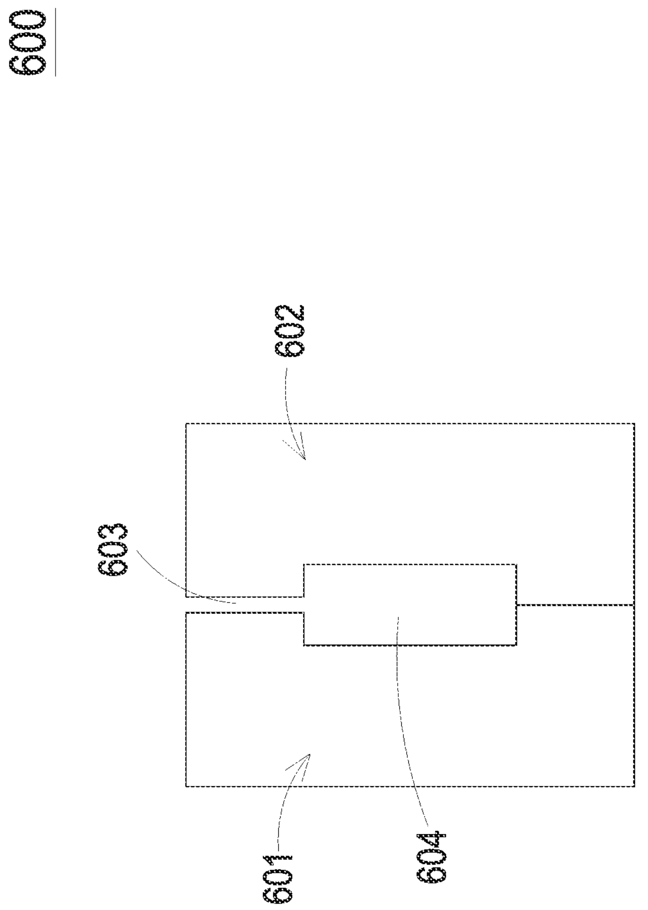


FIG. 9

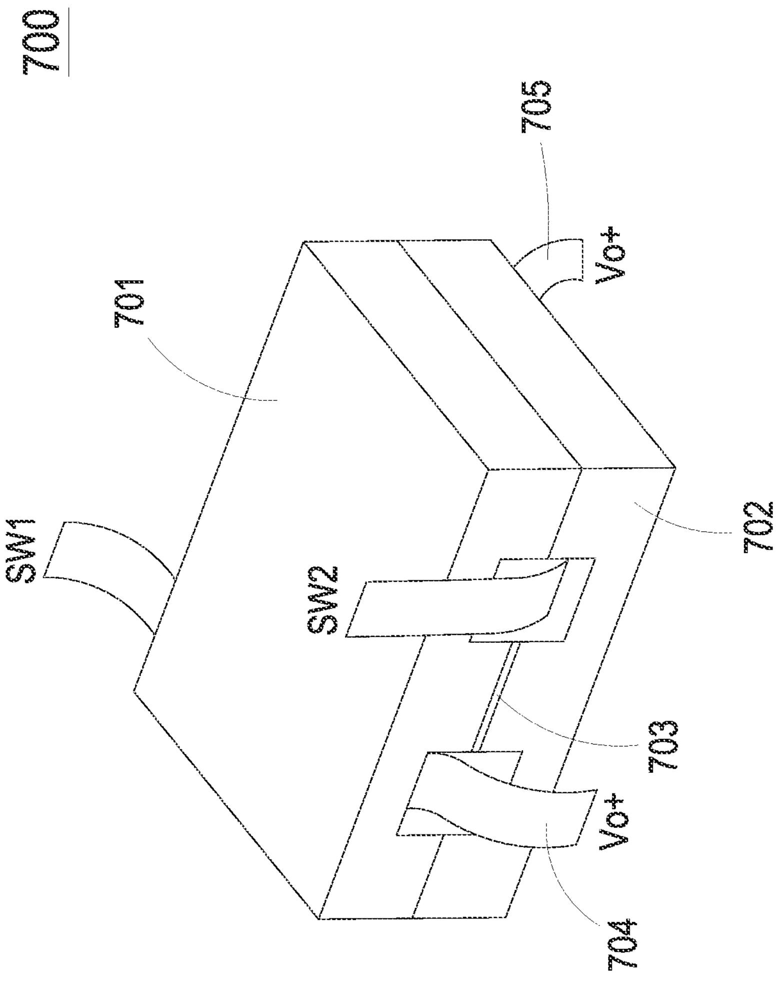


FIG. 10

POWER MODULE AND APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation application of U.S. application Ser. No. 17/672,192 filed on Feb. 15, 2022, which is a continuation application of U.S. patent application Ser. No. 16/591,436 filed on Oct. 2, 2019 and issued as U.S. Pat. No. 11,282,632 on Mar. 22, 2022, which claims the benefit of U.S. Provisional Application Ser. No. 62/743,251 filed on Oct. 9, 2018, claims the benefit of U.S. Provisional Application Ser. No. 62/770,432 filed on Nov. 21, 2018, claims priority to China Patent Application No. 201811519354.1 filed on Dec. 12, 2018, and claims priority to China Patent Application No. 201910900102.1 filed on Sep. 23, 2019, the entire contents of which are incorporated herein by reference for all purposes.

FIELD OF THE INVENTION

[0002] The present disclosure relates to a power module, and more particularly to a power module capable of reducing the power loss and enhancing the heat dissipating efficiency.

BACKGROUND OF THE INVENTION

[0003] FIG. **1**A is a schematic side view illustrating the configuration of a conventional electronic device. FIG. **1**B is a schematic exploded view illustrating the structure of a power module of the electronic device as shown in FIG. **1**A. As shown in FIGS. **1**A and **1**B, the conventional electronic device **6** includes a central processing unit (CPU) **7**, a power module **8** and a system board **9**. The power module **8** is served as a Voltage Regulator Module (VRM) and converts an input power into a regulated power to be supplied to the central processing unit **7**. The power module **8** and the central processing unit **7** are disposed on a same surface of the system board **9**. The power module **8** includes a magnetic core **91**, a printed circuit board (PCB) **92** and a plurality of copper bars **93**, **94**. The copper bars **93**, **94** form the output inductors with the magnetic core **91**. There is a gap **95** formed between the printed circuit board **92** and the magnetic core **91**. The power elements can be disposed on the printed circuit board **92** and located in the gap **95**. In this conventional electronic device **6**, the thermal resistance between the thermal sources, for example the copper bars **93**, **94** or the power elements, and the surface of the printed circuit board **92** of the power module **8** is small. The heat generated from the power module **8** can be conducted to the system board **9**.

[0004] Because of the increasing output current of the voltage regulator module, the output voltage drop is becoming larger. Now, in order to increase the performance of dynamic of the voltage regulator module and enhance the main frequency of the central processing unit, there may be a better solution that the central processing unit and the voltage regulator module can be disposed on the opposite surfaces of the system board to shorten the path between the output of the voltage regulator module and the central processing unit. However, if the central processing unit and the voltage regulator module are disposed on the opposite surfaces of the system board, the power module can't meet the specification of thermal because the heat from the power module fails to be conducted to the system board due to the other thermal source, for example the central processing unit. The power module has a first surface in contact with a case of the electronic device and a second surface fixed on the system board. The thermal resistance between the thermal sources of the power module and the first surface of the power module is larger than the thermal resistance between the thermal sources of the power module and the second surface of the power module. Therefore, the effect of the thermal conduction between the power module and the case of the electronic device is not satisfied.

SUMMARY OF THE INVENTION

[0005] An object of the present disclosure provides a power module or an apparatus. The power module or the apparatus can reduce the power loss of output inductors. Besides, it is benefit for the power module to conduct the heat to a case of the electronic device or the apparatus to conduct a heat-dissipating substrate of the apparatus. Moreover, suitable inductance of the output inductors of the power module or the apparatus can be obtained.

[0006] In accordance with a first aspect of the present disclosure, an apparatus is provided. The apparatus includes a heat-dissipating substrate, a power circuit and a magnetic assembly. The heat-dissipating substrate comprises a thermal contact surface. The power circuit comprises at least one switch element in contact with the thermal contact surface of the heat-dissipating substrate, wherein the heat generated from the at least one switch element is conducted to the heat-dissipating substrate through the thermal contact surface and dissipated by the heat-dissipating substrate. The magnetic assembly comprises at least one first electrical conductor and a magnetic core module comprising at least one hole, wherein the at least one first electrical conductor passes through the at least one hole, and a terminal of the at least one first electrical conductor is electrically connected to the at least one switch element. The heat-dissipating substrate, the power circuit and the magnetic assembly are arranged in sequence along a same direction. A projection of the power circuit on the thermal contact surface partially overlaps a projection of the magnetic assembly on the thermal contact surface.

[0007] In accordance with a second aspect of the present disclosure, an apparatus is provided. The apparatus includes a power circuit, a magnetic assembly and a conductive assembly. The power circuit comprises at least one switch element. The magnetic assembly comprises at least one first electrical conductor and a magnetic core module comprising at least one hole, wherein the at least one first electrical conductor passes through the at least one hole. The conductive assembly comprises a second circuit board, wherein the second circuit board comprises a first surface, a second surface opposite to the first surface and a plurality of first conductive parts, wherein a first terminal of the at least one first electrical conductor of the magnetic assembly is fixed on the second surface, and the plurality of first conductive parts are disposed on the first surface, wherein the at least one first electrical conductor is electrically connected to at least one of the plurality of first conductive parts through the second circuit board, and the switch element is electrically connected to a part of the plurality of the first conductive parts through the second circuit board. A second terminal of the first electrical conductor is connected to the switch element, and the power circuit, the magnetic assembly and the conductive assembly are arranged in sequence along a same direction. A projection of the power circuit on the first surface of the second circuit board and a projection of the magnetic assembly on the first surface of the second circuit board are partially overlap, the projection of the power circuit on the first surface of the second circuit board and a projection of the plurality of first conductive parts on the first surface of the second circuit board are partially overlap.

[0008] From the above descriptions, the present disclosure provides a power module and an apparatus. Since the power module of the present disclosure employs the first electrical conductors as the windings of the output inductors, the power loss of the output inductors can be reduced. In addition, since the first electrical conductors have good thermal conductivity and shorter length, the thermal resistance between the thermal sources and the case or the heat-dissipating substrate of the electronic device is reduced by the first electrical conductors. Therefore, it is benefit to the power module to conduct the heat to the case of the electronic device or the heat-dissipating substrate of the electronic device. At the same time, suitable inductance can be obtained according to the length of the first electrical conductors and the cross-sectional area of the magnetic core. Moreover, since some of the pins of the signal PIN combination are plugged into the half-holes of the second surface of the first printed circuit board or are directly soldered on the second surface of the first printed circuit board without passing through the through-holes of the first printed circuit board, it can save the area of the first surface of the first printed circuit board. Therefore, additional electronic elements can be settled on this saved area of the first surface of the first printed circuit board so as to increase the power density of the power module.

[0009] The above contents of the present disclosure will become more readily apparent to those ordinarily skilled in the art after reviewing the following detailed description and accompanying drawings, in which:

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] FIG. **1**A is a schematic side view illustrating the configuration of a conventional electronic device;

[0011] FIG. **1**B is a schematic exploded view illustrating the structure of a power module of the electronic device as shown in FIG. **1**A;

[0012] FIG. **2**A is a schematic exploded view illustrating a power module according to an embodiment of the present invention;

[0013] FIG. **2**B is a schematic exploded view illustrating the power module of FIG. **2**A and taken along opposite viewpoint;

[0014] FIG. **3** is a schematic circuit diagram illustrating an equivalent circuit of a voltage regulator module formed by the power module of FIG. **2**A;

[0015] FIG. **4** is a schematic assembled view illustrating the power module of FIG. **2**A assembled with a central processing unit and a system board;

[0016] FIG. **5** is a cross-sectional view illustrating the magnetic core module of FIG. **2**A according to a first embodiment of the present disclosure;

[0017] FIG. **6** is a cross-sectional view illustrating the magnetic core module according to a second embodiment of the present disclosure;

[0018] FIG. **7** is a cross-sectional view illustrating the magnetic core module according to a third embodiment of the present disclosure;

[0019] FIG. **8** is a cross-sectional view illustrating the magnetic core module according to a fourth embodiment of the present disclosure;

[0020] FIG. **9** is a cross-sectional view illustrating the magnetic core module according to a fifth embodiment of the present disclosure; and

[0021] FIG. **10** is a schematic assembled view illustrating the magnetic core module of the power module assembled with the first electrical conductors of the power module when the power module forms a 2-phase buck converter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0022] The present disclosure will now be described more specifically with reference to the following embodiments. It is to be noted that the following descriptions of preferred embodiments of this disclosure are presented herein for purpose of illustration and description only. It is not intended to be exhaustive or to be limited to the precise form disclosed.

[0023] FIG. **2**A is a schematic exploded view illustrating a power module according to an embodiment of the present invention. FIG. **2**B is a schematic exploded view illustrating the power module of FIG. **2**A and taken along opposite viewpoint. FIG. **3** is a schematic circuit diagram illustrating an equivalent circuit of a voltage regulator module formed by the power module of FIG. **2**A. The power module **2** (hereinafter also referred to as an apparatus) can form a voltage regulator module (VRM) **1** which can be applied into an electronic device. The voltage regulator module **1** can be for example but not limited to 4-phase buck converter. The voltage regulator module **1** comprises a plurality of power circuits **10**, a plurality of output inductors L, a controller **11** and at least one output capacitor Cout. Each of the power circuits **10** is electrically connected with a terminal SW of a corresponding output inductor L to form a phase buck circuit. Therefore, the voltage regulator module **1** comprises four phase buck circuits, which are connected in parallel and connected between a power source **12** and a first terminal of the output capacitor Cout. Besides, each of the power circuits **10** comprises at least one switch element and a driver which is used to drive the at least one switch element. Moreover, the output inductors L can be independent with each other. In other embodiment, the output inductors L can also be coupled together to reduce the ripple of the output current of the voltage regulator module **1**. The controller **11** senses the output voltage and the output current of every phase buck circuit to generate pulse width modulation signals to control every phase buck circuit. The first terminal of the output capacitor Cout forms a positive output terminal (Vo+) of the voltage regulator module **1**, and a second terminal of the output capacitor Cout is connected with a ground and forms a negative output terminal (Vo−) of the voltage regulator module **1**.

[0024] As shown in FIGS. **2**A and **2**B, the power module **2** comprises a first circuit board assembly **3** and a magnetic assembly **4**. The first circuit board assembly **3** comprises a first printed circuit board **101** and at least one power circuit **10**. The magnetic assembly **4** comprises a magnetic core module **102** and a plurality of first electrical conductors **104**. The first printed circuit board **101** has a first surface **101***a* and a second surface **101***b*. Besides, the power circuits **10** shown in FIG. **3** are settled on the first surface **101***a* of the first printed circuit board **101**. The first printed circuit board

101 with the power circuits **10** may be in contact with a case **13** (as shown in FIG. **4**) of the electronic device so that the heat generated from the power module **2** can be conducted to the case **13** of the electronic device by the first printed circuit board **101**. The operations of the power circuits **10** cause the main portion of heat of the power module **2**, and the power circuits **10** are fitted together with the case **13** of the electronic device so that the heat from the power circuits **10** can be conducted to the case **13** directly. In this embodiment, the number of the first electrical conductors **104** corresponds to the number of the output inductors L shown in FIG. **3**. Preferably but not exclusively, the power module **2** comprises four first electrical conductors **104**. A first terminal of each first electrical conductor **104** which is connected with the corresponding power circuit **10** is soldered on the second surface **101***b* of the first printed circuit board **101**. The magnetic core module **102** comprises a plurality of holes **108**. In this embodiment, the number of the holes **108** corresponds to the number of the first electrical conductors **104**. Preferably but not exclusively, the magnetic core module **102** comprises four holes **108**, and each of the holes **108** is corresponding in position to the corresponding first electrical conductor **104**. The four first electrical conductors **104** pass through the four holes **108** of the magnetic core module **102** respectively so that the four output inductors L of the voltage regulator module **1** can be formed by the combination of the magnetic core module **102** and the four first electrical conductors **104**.

[0025] FIG. **4** is a schematic assembled view illustrating the power module of FIG. **2**A assembled with a central processing unit and a system board. When the power module **2** is applied into the electronic device to assembly with a central processing unit **7** and a system board **9** of the electronic device, the power module **2** and the central processing unit **7** are disposed on the opposite surfaces of the system board **9**. The system board **9** has a first surface **9***a* and a second surface **9***b*. The power module **2** disposed on the first surface **9***a* of the system board **9** is corresponding in position to the central processing unit **7** disposed on the second surface **9***b* of the system board **9**.

[0026] From the above descriptions, since the power module **2** of the present disclosure employs the first electrical conductors **104** as the windings of the output inductors L, the power module **2** can reduce the power loss of the output inductors L. In addition, since the first electrical conductors **104** comprise good thermal conductivity and shorter length, the thermal resistance between the output inductors L and the first printed circuit board **101** is reduced by the first electrical conductors **104**. Therefore, it is benefit to the power module **2** to conduct the heat to the case **13** of the electronic device. At the same time, suitable inductance can be obtained according to the length of the first electrical conductors **104** and the cross-sectional area of the magnetic core module **102**.

[0027] In some embodiments, the power module **2** comprises a plurality of second electrical conductors **105** soldered on one edge of the second surface **101***b* of the first printed circuit board **101**. One or more of the plurality of second electrical conductors **105** form a positive input terminal of the voltage regulator module **1**, and the other of the plurality of second electrical conductors **105** form a negative input terminal of the voltage regulator module **1**. Since the power module **2** of the present disclosure employs the second electrical conductors **105** as the input terminal of the voltage regulator module **1**, the power module **2** can reduce the equivalent series resistance ESR and the equivalent series inductance ESL so that the performance of the voltage regulator module **1** is enhanced. In some embodiments, the power module **2** comprises a third electrical conductor **106** soldered on the other edge of the second surface **101***b* of the first printed circuit board **101**. The third electrical conductor **106** forms the negative output terminal (Vo−) of the voltage regulator module **1**. Since the power module **2** of the present disclosure employs the third electrical conductor **106** as the negative output terminal (Vo−) of the voltage regulator module **1**, the power module **2** can reduce the equivalent series resistance ESR and the equivalent series inductance ESL so that the dynamic switching performance of the voltage regulator module **1** is enhanced. Moreover, since the second electrical conductors **105** and the third electrical conductor **106** comprise good thermal conductivity respectively, the thermal resistance between the second electrical conductors **105** and the first printed circuit board **101** and the thermal resistance between the third electrical conductor **106** and the first printed circuit board **101** is reduced. Therefore, it is benefit to the power module **2** to conduct the heat to the case **13** of the electronic device. In this embodiment, the first electrical conductors **104**, the second electrical conductors **105** and the third electrical conductors **106** are made of metallic material for example but not limited to copper, aluminum or alloy. In some embodiments, considering performance and cost, preferably but not exclusively, the first electrical conductors **104**, the second electrical conductors **105** and the third electrical conductors **106** are made of copper. The shape of the electrical conductors isn't limited, which is designed according to the practical requirements.

[0028] Furthermore, in order to fix the first electrical conductors **104**, the second electrical conductors **105** and the third electrical conductors **106** on the second surface **101***b* of the first printed circuit board **101** when reflowing, the four first electrical conductors **104** are stuck and glued with the magnetic core module **102**, and the second electrical conductors **105** and the third electrical conductor **106** are glued at the edge of the magnetic core module **102**.

[0029] In other embodiment, the first printed circuit board **101** comprises a plurality of through-holes **202** and a plurality of half-holes (not shown in FIGS. **2**A and **2**B). Each of the through-holes **202** run through the first printed circuit board **101**, and the half-holes located at the second surface **101***b* do not run through the first printed circuit board **101**. Besides, the power module **2** comprises a signal PIN combination **107** (i.e. a signal communication part) at one edge of the second surface **101***b* of the first printed circuit board **101**. The signal PIN combination **107** comprises a plurality of pins. Each pin comprises a first contact part and a second contact part, which are opposite to each other. The first contact parts of some pins of the signal PIN combination **107** pass through the through-holes **202** of the first printed circuit board **101**. The first contact parts of the other pins of the signal PIN combination **107** are plugged into the half-holes of the second surface **101***b* of the first printed circuit board **101** by soldering or be directly soldered on the second surface **101***b* of the first printed circuit board **101**. Besides, the lengths of the pins of the signal PIN combination **107** can be different due to the different contacting methods. Since some of the pins of the signal PIN combination **107** are plugged into the half-holes of the second surface **101***b* of the first printed circuit board **101** or are directly soldered on the second surface **101**_b_ of the first printed circuit board **101** without passing through the through-holes **202** of the first printed circuit board **101**, it can save the area of the first surface **101**_a_ of the first printed circuit board **101**. Therefore, additional electronic elements can be settled on this saved area of the first surface **101**_a_ of the first printed circuit board **101** so as to increase the power density of the power module **2**.

[0030] In some embodiments, the first surface **9**_a_ of the system board **9** comprises a plurality of soldering pads (not shown in FIGS. **2**A and **2**B). The first electrical conductors **104**, the second electrical conductors **105**, the third electrical conductor **106** and the pins of the signal PIN combination **107** can be soldered on the corresponding soldering pads, respectively.

[0031] FIG. **5** is a cross-sectional view illustrating the magnetic core module of FIG. **2**A according to a first embodiment of the present disclosure. As shown in FIG. **5**, the magnetic core module **102** comprises two E cores **401**, **402** and one I core **403**. The I core **403** is disposed between the two E cores **401**, **402** so that four holes **108** of the magnetic core module **102** are formed by the combination of the two E cores **401**, **402** and the I core **403**. Besides, a plurality of gaps **404**_a_, **404**_b_, **405**_a_ and **405**_b_ are formed and located at the intersections between the I core **403** and the two side columns of the two E cores **401**, **402**, wherein the E core **401** comprises two side columns **406**_a_, **406**_b_ and a middle column **406**_c_, and the E core **402** comprises two side columns **407**_a_, **407**_b_ and a middle column **407**_c_. Preferably, the magnetic core module **102** has a cross-sectional area in 田-shaped.

[0032] FIG. **6** is a cross-sectional view illustrating the magnetic core module according to a second embodiment of the present disclosure. As shown in FIG. **6**, the magnetic core module **410** of the power module **2** of the present disclosure comprises single core integrated molding. In other words, the magnetic core module **410** can be an integrated structure in one piece. The magnetic core module **410** comprises a plurality of gaps **414**_a_, **414**_b_, **415**_a_ and **415**_b_ located at two side columns of the magnetic core module **410**. Besides, the DC flux density Bdc at the middle column of the magnetic core module **410** counteracts, and there is no magnetic saturation at the middle column of the magnetic core module **410**. Moreover, the sectional area of the middle column of the magnetic core module **410**≤0.8×(the sectional area of one side column of the magnetic core module **410**+the sectional area of the other side column of the magnetic core module **410**). Preferably, the magnetic core module **410** has a cross-sectional area in 田-shaped.

[0033] In some embodiments, as shown in FIGS. **2**A and **2**B, the power module **2** comprises a second circuit board assembly **5** (hereinafter also referred to as a conductive assembly **5**). The second circuit board assembly **5** comprises a second printed circuit board **103** and at least one output capacitor Cout. The second printed circuit board **103** has a first surface **103**_a_ and a second surface **103**_b_. The second printed circuit board **103** comprises a plurality of soldering pads (not shown in FIG. **2**B) disposed on the first surface **103**_a_ and used to be soldered with the system board **9** so that the second printed circuit board **103** can be fixed on the system board **9** by soldering. Besides, the second printed circuit board **103** comprises a plurality of first soldering pads **204**, a plurality of second soldering pads **205** and a third soldering pad **206** disposed on the second surface **103**_b_ of the second printed circuit board **103**. A second terminal of each first electrical conductor **104** which forms the positive output terminal (Vo+) of the voltage regulator module **1** can be soldered on the corresponding first soldering pad **204**. One terminal of the second electrical conductors **105** can be soldered on the corresponding second soldering pads **205**. One terminal of the third electrical conductor **106** can be soldered on the corresponding third soldering pad **206**. Furthermore, the second surface **103**_b_ of the second printed circuit board **103** comprises the half-hole combination **203** which comprises a plurality of half-holes. The second contact parts of the pins of the signal PIN combination **107** are plugged into the half-holes of the half-hole combination **203** of the second surface **103**_b_ of the second printed circuit board **103** by soldering. In other embodiment, the second contact parts of the pins of the signal PIN combination **107** can be soldered on the second surface **103**_b_ of the second printed circuit board **103** directly. Besides, the output capacitor Cout is disposed on the second surface **103**_b_ of the second printed circuit board **103**. In other embodiment, the output capacitor Cout is disposed on the system board **9** when the second printed circuit board **103** is omitted.

[0034] Furthermore, the voltage regulator module which is formed by the power module of the present disclosure also can be for example but not limited to a 2-phase buck converter or a 1-phase buck converter. When the voltage regulator module is a 2-phase buck converter, the voltage regulator module comprises two output inductors. Therefore, the differences between of the power module which forms 2-phase buck converter and the power module **2** which forms 4-phase buck converter shown in FIG. **2**A are on the magnetic core module and the first electrical conductors. In this embodiment, the power module which forms 2-phase buck comprises two first electrical conductors. FIG. **7** is a cross-sectional view illustrating the magnetic core module according to a third embodiment of the present disclosure. When the power module forms 2-phase buck converter, the magnetic core module **500** of the power module includes two E cores **501**, **502** so that two holes **504** of the magnetic core module **500** are formed by the combination of the two E cores **501**, **502**. The E core **501** comprises two side columns **506**_a_ and **506**_b_ and a middle column **506**_c_, and the E core **502** comprises two side columns **507**_a_ and **507**_b_ and a middle column **506**_c_. A gap **503**_a_ is formed and located between the side column **506**_a_ and the side column **507**_a_. A gap **503**_b_ is formed and located between the side column **506**_b_ and the side column **507**_b_. Moreover, the two first electrical conductors pass through the two holes **504** respectively to form the two output inductors.

[0035] FIG. **8** is a cross-sectional view illustrating the magnetic core according to a fourth embodiment of the present disclosure. In some embodiments, when the power module forms 2-phase buck converter, the magnetic core module **510** of the power module may include one E core **512** and one I core **511**. A gap **513**_a_ is formed and located between one side column **512**_a_ of the E core **512** and the I core **511**. A gap **513**_b_ is formed and located between the other side column **512**_b_ of the E core **512** and the I core **511**. Besides, the DC flue density Bdc at the middle column **512**_c_ of the magnetic core module **510** counteracts, and there is no magnetic saturation at the middle column **512**_c_ of the magnetic core module **510**. Moreover, the sectional area of the middle column **512***c* of the magnetic core module **510**≤0.8×(the sectional area of one side column **512***a* of the magnetic core module **510**+the sectional area of the other side column **512***b* of the magnetic core module **510**). In other embodiments, the magnetic core module **510** may be integrated molding. In other words, the magnetic core module **510** can be an integrated structure in one piece.

[0036] When the voltage regulator module is a 1-phase buck converter, the voltage regulator module comprises one output inductor. Therefore, the differences between of the power module which forms 1-phase buck converter and the power module **2** which forms 4-phase buck converter shown in FIG. **2**A are on the magnetic core module and the first electrical conductors. In this embodiment, the power module which forms 1-phase buck comprises one first electrical conductor. FIG. **9** is a cross-sectional view illustrating the magnetic core according to a fifth embodiment of the present disclosure. When the power module forms 1-phase buck converter, the magnetic core module **600** of the power module includes two U cores **601**, **602** so that one hole **604** of the magnetic core module **600** is formed by the combination of the two U cores **601**, **602**. A gap **603** is formed and located between one side column of the U core **601** and one side column of the U core **602**. Moreover, the one first electrical conductor passes through the hole **604** to form the output inductor. In other embodiment, the magnetic core module **600** may be formed by one U core and one I core. Besides, the magnetic core module **600** can be integrated molding. In other words, the magnetic core **600** can be an integrated structure in one piece.

[0037] Furthermore, the output inductors can also be coupled together to reduce the ripple of the output current of voltage regulator module. For example, when the voltage regulator module is the 4-phase buck converter, the four output inductors are coupled together. When the voltage regulator module is the 2-phase buck converter, the two output inductors are coupled together. The following will exemplarily illustrate the structures of the magnetic core module and the first electrical conductors of the power module when the power module is the 2-phase buck converter and the output inductors of the 2-phase buck converter are coupled together. FIG. **10** is a schematic assembled view illustrating the magnetic core module of the power module assembled with the first electrical conductors of the power module when the power module forms a 2-phase buck converter. The magnetic core module **700** of the power module comprises two E cores **701** and **702**. The gap **703** is formed and located at a middle column of the magnetic core module **700**. Besides, the two first electrical conductors **704** and **705** can be formed by two copper bars which are flexible. The combination of the magnetic core module **700** and two first electrical conductors **704**, **705** can form two coupled output inductors. One terminal (SW1/SW2) of the two electrical conductors **704** and **705** are fixed on the first printed circuit board of the power module by soldering. The other terminal (Vo+) of the two electrical conductors **704** and **705** are connected to the second printed circuit board or the system board. In the magnetic core module **700**, there is a gap **703** formed at the middle column of the magnetic core module **700**, and the DC flux density Bdc at the middle column of the magnetic core **700** overlays, and the AC flex density Bac at the middle column of the magnetic core **700** counteracts. Obviously, the power module using 4-phase buck converter also can use the coupled output inductors based on the same principle shown in FIG. **10**.

[0038] From the above descriptions, the present disclosure provides a power module. Since the power module of the present disclosure employs the first electrical conductors as the windings of the output inductors, the power loss of the output inductors can be reduced. In addition, since the first electrical conductors have good thermal conductivity and shorter length, the thermal resistance between the thermal sources and the case of the electronic device is reduced by the first electrical conductors. Therefore, it is benefit to the power module to conduct the heat to the case of the electronic device. At the same time, suitable inductance can be obtained according to the length of the first electrical conductors and the cross-sectional area of the magnetic core. Moreover, since some of the pins of the signal PIN combination are plugged into the half-holes of the second surface of the first printed circuit board or are directly soldered on the second surface of the first printed circuit board without passing through the through-holes of the first printed circuit board, it can save the area of the first surface of the first printed circuit board. Therefore, additional electronic elements can be settled on this saved area of the first surface of the first printed circuit board so as to increase the power density of the power module.

[0039] While the disclosure has been described in terms of what is presently considered to be the most practical and preferred embodiments, it is to be understood that the disclosure needs not be limited to the disclosed embodiment. On the contrary, it is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims which are to be accorded with the broadest interpretation so as to encompass all such modifications and similar structures.

What is claimed is:

1. A power module, comprising:

a power circuit comprising at least one switch element;

a magnetic assembly comprising at least one first electrical conductor and a magnetic core module, wherein at least one first electrical conductor passes through the magnetic module, and a terminal of the at least one first electrical conductor is electrically connected to the at least one switch element; and

a first circuit board comprising a first surface and a second surface opposite to the first surface, wherein the power circuit is disposed on the first surface;

wherein the power circuit and the magnetic assembly are arranged in sequence along a same direction;

wherein the power module further comprises a plurality of second electrical conductors, wherein one end of each of the second electrical conductors is disposed on one edge of the second surface of the first circuit board and electrically connected with the power circuit.

2. The power module according to claim **1**, wherein the magnetic core module comprising at least one hole, wherein the at least one first electrical conductor passes through the at least one hole.

3. The power module according to claim **1**, wherein the power module further comprises a third electrical conductor, wherein one end of the third electrical conductor is disposed on the other edge of the second surface of the first circuit board and electrically connected with the power circuit, the other end of the third electrical conductor is disposed on and electrically connected with a third conductive part.

4. The power module according to claim **3**, wherein the power module further comprises a second circuit board, wherein the second circuit board comprises a first surface, a second surface opposite to the first surface and a plurality of first conductive parts, wherein a first terminal of the at least one first electrical conductor of the magnetic assembly is fixed on the second surface of the second circuit board.

5. The power module according to claim **4**, wherein the plurality of first conductive parts are disposed on the first surface of the second circuit board, wherein the at least one first electrical conductor is electrically connected to at least one of the plurality of first conductive parts through the second circuit board, and the at least one switch element is electrically connected to a part of the plurality of first conductive parts through the second circuit board.

6. The power module according to claim **4**, wherein the second circuit board comprises the third conductive part disposed on the second surface thereof.

7. The power module according to claim **4**, wherein the second circuit board comprises at least one output capacitor disposed on the second surface of the second circuit board.

8. The power module according to claim **1**, wherein the other end of each of the second electrical conductors is disposed on and electrically connected with a corresponding one of a plurality of second conductive parts.

9. The power module according to claim **4**, wherein the second circuit board comprises the plurality of second conductive parts disposed on the second surface thereof.

10. The power module according to claim **1**, wherein the second electrical conductors are disposed at one edge of the magnetic core module.

11. The power module according to claim **3**, wherein the third electrical conductor are disposed at one edge of the magnetic core module.

12. The power module according to claim **1**, wherein the first circuit board further comprises a plurality of half-holes disposed in the second surface of the first circuit board and a plurality of through-holes, wherein the power module comprises a signal pin combination with a plurality of pins, wherein the signal pin combination is located at one edge of the second surface of the first circuit board, and each of the plurality of pins comprises a first contact part and a second contact part, wherein the first contact parts of some of the pins of the signal pin combination pass through the through-holes of the first circuit board, and the first contact parts of the other pins of the signal pin combination are plugged into the half-holes of the second surface of the first circuit board by soldering.

13. The power module according to claim **4**, wherein the second surface of the second circuit board further comprises a half-hole combination with a plurality of half-holes, wherein the second contact parts of the pins of the signal pin combination are plugged into the half-holes of the half-hole combination of the second surface of the second circuit board.

14. An apparatus, comprising: a power module and a system board, wherein the system board comprises a plurality of second conductive parts, and the power module comprises:

a power circuit comprising at least one switch element;

a magnetic assembly comprising at least one first electrical conductor and a magnetic core module, wherein at least one first electrical conductor passes through the magnetic module, and a terminal of the at least one first electrical conductor is electrically connected to the at least one switch element;

a first circuit board comprising a first surface and a second surface opposite to the first surface, wherein the power circuit is disposed on the first surface; and

a plurality of second electrical conductors, wherein one end of each of the second electrical conductors is disposed on one edge of the second surface of the first circuit board and electrically connected with the power circuit, the other end of each of the second electrical conductors is disposed on and electrically connected with the corresponding one of the plurality of second conductive parts;

wherein the power circuit, the magnetic assembly and the system board are arranged in sequence along a same direction.

15. The apparatus according to claim **14**, wherein the magnetic core module comprising at least one hole, wherein the at least one first electrical conductor passes through the at least one hole.

16. The apparatus according to claim **14**, wherein the power module further comprises a third electrical conductor, wherein one end of the third electrical conductor is disposed on the other edge of the second surface of the first circuit board and electrically connected with the power circuit, the other end of the third electrical conductor is disposed on and electrically connected with a third conductive part disposed on the system board.

17. The apparatus according to claim **14**, wherein the system board comprises at least one output capacitor.

18. The apparatus according to claim **14**, wherein the second electrical conductors are disposed at one edge of the magnetic core module.

19. The apparatus according to claim **16**, wherein the third electrical conductor are disposed at one edge of the magnetic core module.

20. The apparatus according to claim **14**, wherein the first circuit board further comprises a plurality of half-holes disposed in the second surface of the first circuit board and a plurality of through-holes, wherein the power module comprises a signal pin combination with a plurality of pins, wherein the signal pin combination is located at one edge of the second surface of the first circuit board, and each of the plurality of pins comprises a first contact part and a second contact part, wherein the first contact parts of some of the pins of the signal pin combination pass through the through-holes of the first circuit board, and the first contact parts of the other pins of the signal pin combination are plugged into the half-holes of the second surface of the first circuit board by soldering.

21. The apparatus according to claim **14**, wherein the second surface of the system board further comprises a half-hole combination with a plurality of half-holes, wherein the second contact parts of the pins of the signal pin combination are plugged into the half-holes of the half-hole combination of the system board.

22. The apparatus according to claim **14**, wherein the system board comprises a plurality of first conductive parts, the at least one first electrical conductor is electrically connected to at least one of the plurality of first conductive parts.

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