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(54) **INDUCTOR**

(57) The object of the present invention is to provide an inductor capable of realizing a voltage conversion circuit which is compact in size and is able to provide a suitable output. To achieve the above described object, the inductor according to the invention has a core and a plurality of windings, and the core comprises a plurality

of arms for windings around which the plurality of windings are respectively wound; at least one common arm which forms magnetic loops with the plurality of arms for windings, respectively; and a pair of base parts. The plurality of arms for windings and the common arm are located between the pair of base parts.

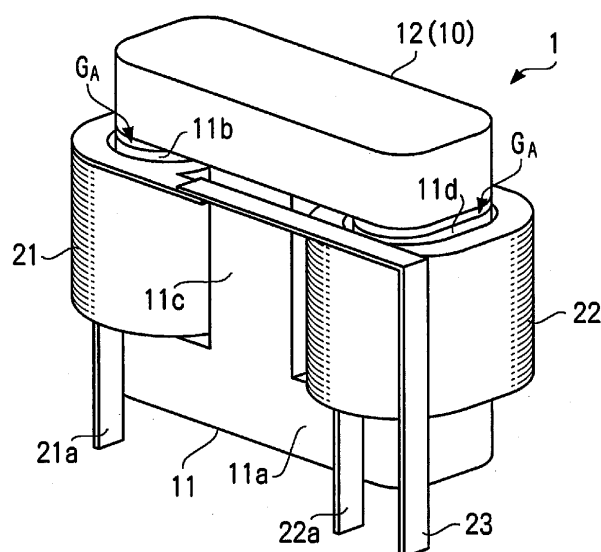


FIG. 1

Description

TECHNICAL FIELD

[0001] The present invention relates an inductor used for, for example, a voltage conversion circuit.

BACKGROUND ART

[0002] As a voltage conversion circuit for boosting a AC voltage or a DC voltage to a desired voltage, a conversion circuit of an interleave PFC (Power Factor Correct) type described, for example, in Japanese Patent Provisional Publication No. 2007-195282 is used. Fig. 11 illustrates an example of a conversion circuit of an interleave PFC type for a two-phase AC power source. In a conversion circuit S shown in Fig. 11, an AC current from an AC current source E is branched into inductors L_1 and L_2 . By diodes arranged between the AC power source E and the inductors L_1 and L_2 , the directions of the currents flowing through the inductors L_1 and L_2 are kept constant (i.e., in the direction proceeding from the left to the right in Fig. 11). In the following explanation, a terminal of each of the inductors L_1 and L_2 on the upstream side is defined as an input terminal, and a terminal of each of the inductors L_1 and L_2 on the downstream side is defined as an output terminal.

[0003] The output terminal of each of the inductors L_1 and L_2 is branched into two paths. Branched paths on one side are connected to a first output terminal O_1 of the conversion circuit S. Branched paths of the inductors L_1 and L_2 on the other side are connected to a second output terminal O_2 of the conversion circuit S via MOS transistors M_1 and M_2 . An electrolytic capacitor is provided between the first and second output terminals O_1 and O_2 . Gates of the MOS transistors M_1 and M_2 are connected to a controller C. The controller C intermittently transmits a pulse signal to each gate so that the output terminal of each of the inductors L_1 and L_2 is intermittently connected or disconnected to or from the second output terminal O_2 of the conversion circuit S. The controller C supplies the pulse signals to the MOS transistors M_1 and M_2 while shifting the phases of the pulse signals transmitted to the MOS transistors M_1 and M_2 by 180° with respect to each other.

[0004] By connecting the AC power source E to the conversion circuit S configured as described above, it becomes possible to obtain, at the output terminals O_1 and O_2 , a DC current having a voltage V_{OUT} which is higher than a voltage V_{IN} of the AC power source E

[0005] When an AC current is converted by a conversion circuit using a single inductor, the output current or the output voltage thereof fluctuates in a mountain-like form. That is, the output current or the output voltage has many ripples. By contrast, when a conversion circuit of an interleave PFC type is used, a plurality of currents whose ripples are shifted with respect to each other are combined, an suitable current having a small ripples can

be obtained.

OBJECT OF THE INVENTION

[0006] However, the conversion circuit of the conventional interleave type has a drawback that the size of the conversion circuit becomes large because a plurality of inductors are used.

[0007] The present invention is made in consideration of the above described circumstances. That is, the object of the present invention is to provide an inductor capable of realizing a voltage conversion circuit which is compact in size and is able to provide a suitable output.

MEANS FOR SOLVING THE PROBLEM

[0008] To achieve the above described object, the inductor according to the present invention has a core and a plurality of windings, and the core comprises a plurality of arms for windings around which the plurality of windings are respectively wound; at least one common arm which forms magnetic loops with the plurality of arms for windings, respectively; and a pair of base parts. The plurality of arms for windings and the common arm are located between the pair of base parts.

[0009] In the above described configuration, the common arm may be integrally formed with one of the pair of base parts and closely contacts with the other of the pair of base parts.

[0010] The common arm may have a first divided arm part formed integrally with one of the pair of base parts, and a second divided arm part formed integrally with the other of the pair of base parts, and the first divided arm part and the second divided arm part may closely contact with each other.

[0011] It is preferable that magnetic resistances of the plurality of arms for windings are larger than a magnetic resistance of the common arm. For example, the plurality of arms for windings are separately provided from each of the pair of base parts, and plate-like gap members are sandwiched between the pair of base parts and the plurality of arms for windings. In this case, the gap members are made of resin material. Material forming the plurality of arms for windings may have a magnetic resistance larger than a magnetic resistance of material forming the pair of base parts and the common arm. For example, the plurality of arms for windings are dust cores, and each of the pair of base parts and the common arm is a ferrite core. In place of the configuration where the gap members are sandwiched between the base parts and the plurality of arms for windings, the plurality of arms for windings may be formed integrally with one of the pair of base parts and air gaps may be formed between the other of the pair of base parts and the plurality of arms for windings.

[0012] The number of the plurality of arms for windings may be two, and the plurality of arms for windings and the common arm may be arranged in a line such that,

between the pair of base parts, the common arm is positioned between the two arms for windings. Alternatively, the number of the at least one common arm may be two, and the plurality of arms for windings and the two common arms may be arranged in a line such that, between the pair of base parts, the plurality of arms for windings are positioned between the two common arms. The pair of base parts may have polygonal shapes, and the plurality of arms for windings may be provided at positions connecting corners of the pair of base parts with each other. In this case, the plurality of arms for windings may be respectively provided at all the corners of the pair of base parts, and the common arm may be located at a position connecting central portions of the pair of base parts with each other. The common arm may be provided at a position connecting outer edge parts of the pair of base parts with each other, and the plurality of arms for windings are not located at the outer edge parts of the pair of base parts. In the above described configuration, the plurality of arms for windings may be provided at opposing corner parts of the pair of base parts.

[0013] The inductor may further include a plurality of auxiliary windings, and the plurality of auxiliary windings may be respectively wound around the plurality of arms for windings.

[0014] It is preferable that magnetic fluxes respectively generated in the common arm by the plurality of arms for windings cancel with each other.

ADVANTAGES OF THE INVENTION

[0015] When the above explained inductor according to the invention is used in a voltage conversion circuit of an interleave PFC type, it becomes possible to cancel the magnetic fluxes of the windings by the common arm. Therefore, the magnitude of the magnetic flux penetrating the common arm can be set to be small. As a result, the cross sectional area of the common arm can be set sufficiently smaller than the cross sectional areas of the arms for windings. When such an inductor is used in a voltage conversion circuit of an interleave PFC type, the volume and the installation area of an inductor can be suppressed as compared to the conventional configuration in which a plurality of inductors are used. Thus, a compact voltage conversion circuit can be realized.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Fig. 1 is a perspective view of an inductor according to a first embodiment of the present invention.

Fig. 2 is a side view generally illustrating the inductor according to the first embodiment of the invention.

Fig. 3 is a side view generally illustrating another example of the inductor according to the first embodiment of the invention.

Fig. 4 is a perspective view of an inductor according to a second embodiment of the invention.

Fig. 5 is a side view generally illustrating an inductor according to a third embodiment of the invention.

Fig. 6 is a perspective view of an inductor according to a fourth embodiment of the invention.

Fig. 7 is a perspective view of an inductor according to a fifth embodiment of the invention.

Fig. 8 is a perspective view of an inductor according to a sixth embodiment of the invention.

Fig. 9 is a perspective view of a core of the inductor according to the sixth embodiment of the invention.

Fig. 10 is an exploded perspective view of the inductor according to the sixth embodiment of the invention.

Fig. 11 is a circuit diagram illustrating an example of a voltage conversion circuit of an interleave PFC type.

EMBODIMENTS

[0017] In the following, embodiments of the present invention are explained in detail with reference to the accompanying drawings. Fig. 1 is a perspective view of an inductor according to a first embodiment of the invention. Fig. 2 is a side view generally illustrating the inductor according to the embodiment. As shown in Fig. 1, the inductor 1 according to the embodiment includes a core 10, a first winding 21 and a second winding 22.

[0018] The core 10 is formed by combining a first block 11 and a second block 12. The first block 11 is an E-shaped type in which three arms including a first arm 11b, a second arm 11c and a third arm 11d extend, approximately in parallel with each other, from a first core part 11a which is a rod-like proximal portion. A second block 12 is a rod-like member, i.e., an I-shaped type, and serves as a second core part making a pair with the first core part 11a. That is, the core 10 is a so-called EI type core. The first winding 21 and the second winding 22 are wound around the first arm 11b and the third arm 11d of the first block 11, respectively. Lower terminals of the first and second windings 21 and 22 are respectively connected to lead wires 21a and 22a, and upper terminals of the first and second windings 21 and 22 are connected to a common lead wire 23.

[0019] As the core 10, a dust core formed by press-molding ferromagnetic powders such as iron, a laminated core formed by laminating steel plates such as Silicon steel, or a ferrite core is used. The first block 11 and the

second block 12 may be of the same type or of different types. The types of the first and third arms 11b and 11d around which the windings 21 and 22 are respectively wound may be different from the type of the central second arm 11c.

[0020] When the current flows through the first winding 21 and the second winding 22 of the inductor 1 configured as described above, a magnetic flux B1 by the first winding 21 and a magnetic flux B2 by the second winding 22 are formed in the core 1 as shown in Fig. 2. The magnetic flux B₁ is formed in the first arm 11b and the second 11c, and the magnetic flux B₂ is formed in the third arm 11d and the second arm 11c. That is, the second arm 11c is penetrated by both of the magnetic fluxes B₁ and B₂.

[0021] Since the winding direction in which the first winding 21 is wound is the inverse of the winding direction in which the second winding 22 is wound, in the second arm 11c the directions of the magnetic fluxes B₁ and B₂ become opposite to each other when the current is supplied from the lead wire 23 to the lead wires 21a and 22a. For this reason, in the second arm 11c the magnetic fluxes B₁ and B₂ cancel with each other, and therefore the magnitude of the magnetic flux penetrating through the second arm 11c becomes small. As a result, the sectional area of the second arm 11c may be sufficiently small relative to the sum of the sectional areas of the first arm 11b and third arm 11d.

[0022] As described above, the first winding 21 and the second winding 22 share a part of the core 10 (i.e., the second arm 11c). Therefore, as compared to a configuration where the first winding 21 and the second winding 22 are respectively wound around separate cores, it becomes possible to considerably decrease the volume and the installation area of an inductor. Therefore, by employing the inductor 1 according to the embodiment in an interleaved PFC circuit, it becomes possible to realize a voltage converter which is compact in size and whose ripple is small. Furthermore, since, in this embodiment, two windings of the inductor are attached to the outer arms, it becomes possible to effectively release heat to the outside without letting heat generated by the windings stay in the central part.

[0023] Since the inductor 1 according to the embodiment is configured such that the length of the central second arm 11c is slightly larger than the length of each of the first arm 11b and the third arm 11d arranged outside of the second arm 11c. Therefore, by forming the core 10 by combining the first block 11 and the second block 12, an air gap G_A is formed between the second block 12 and the first and third arms 11b and 11d. The air gap G_A prevents occurrence of magnetic saturation in the first arm 11b and the third arm 11d.

[0024] Furthermore, no gap is formed between the second block 12 and the central second arm 11c (i.e., the second arm 11c closely contacts with the second block 12). Therefore, the magnetic resistance of a path proceeding from the first arm 11b or the third arm 11d to the second arm 11c becomes sufficiently smaller than

the magnetic resistance of a path between the first arm 11b and the third arm 11d. As a result, almost all the magnetic flux generated by the first winding 21 penetrates the second arm 11c and does not penetrate the third arm 11d. Similarly, almost all the magnetic flux generated by the second winding 22 penetrates the second arm 11c and does not penetrate the first arm 11b. Therefore, it becomes possible to avoid occurrence of a problem that one of the windings causes electromagnetic induction in the other of the windings and thereby a noise is caused on the output.

[0025] As described above, the inductor 1 according to the embodiment has the pair of windings 21 and 22. However, the invention is not limited to the above described configuration. For example, as shown in Fig. 3, a first auxiliary winding 21' and a second auxiliary winding 22' may be respectively provided on the first arm 11b and the third arm 11d, in addition to the first winding 21 and the second winding 22. An inductor 1' having such a configuration is used in a conversion circuit of an interleaved PFC type which operates in a so-called critical mode in which switching of a MOS transistor is executed when it is detected that the current flowing through a winding used for boosting becomes zero (i.e. when a zero-cross is detected). That is, the first auxiliary winding 21' and the second auxiliary winding 22' are connected to a PFC controller which controls the MOS transistor, and the PFC controller detects the amplitude of the current flowing through the first winding 21 and the second winding 22 and controls the switching operation of the MOS transistor based on detection results.

[0026] In addition, the above described configuration is advantageous when two conversion circuit systems of the interleaved type are used. That is, according to the above described configuration, the conversion circuit by the windings 21 and 22 and the conversion circuit by the auxiliary windings 21' and 22' can be formed by a single inductor. When the inductor 1' is used in the two conversion circuits of the interleaved type, it is preferable that the directions of the currents flowing through the auxiliary windings 21' and 22' are determined so that the magnetic flux caused by the current flowing through the auxiliary winding 21' and the magnetic flux caused by the current flowing through the auxiliary winding 22' cancel with each other in the second arm 11c.

[0027] In the above described first embodiment according to the invention, the second arm 11c is configured to have a shape of a rectangular column as shown in Fig. 1. However, the invention is not limited to the above described configuration. For example, an inductor 101 according to a second embodiment of the invention shown as a perspective view in Fig. 4 is configured such that the size D in the depth direction (i.e., the direction perpendicular to both of the axis direction and the arranging direction of a first winding 121 and a second winding 122. The direction pointing from the lower right side to the upper left side) of a central second arm 111c on which the first winding 121 and the second winding 122 are not

arranged is substantially equal to the outer diameter of each of the first winding 121 and the second winding 122. For this reason, the size in depth direction of each of a first core part 111a of the first block 111 and a second block 112 becomes smaller at a point closer to both end part thereof, and becomes larger at a point closer to the center in the width direction (i.e., the part at which the second arm 111c is provided), and takes the maximum value D in the vicinity of the center in the width direction. More specifically, as shown in Fig. 4, each of the first core part 111a of the first core 111 and the second block 112 is formed to be a hexagonal plate, and the first arm 111b and the third arm 111d on which the windings 121 and 122 are respectively provided are arranged to connect two pairs of corner parts 111e and 112a and 111f and 112b defining the opposing corners of the above described respective hexagons.

[0028] Both of a side face 115a of the second arm 111c on the first arm 111b side and a side face 115b of the second arm 111c on the third arm 111d side are formed as concave surfaces formed to be a cylinder extending in the axis direction of the windings 121 and 122. Furthermore, parts of the first winding 121 and the second winding 122 are arranged in the concave parts of the side faces 115a and 115b of the second arm 111c, respectively.

[0029] As described above according to the embodiment, it becomes possible to suppress the size of the inductor 101 in the width direction (i.e., the arranging direction of the first winding 121 and the second winding 122. The direction proceeding from the lower left part to the upper right part of the drawing). Furthermore, according to the embodiment, the size of the second arm 111c in the depth direction is set to be as long as possible within the condition that the size of the inductor 101 in the depth direction is not increased. Therefore, according to the embodiment, an inductor whose installation area and the volume are suppressed can be realized while securing the performance of the inductor by securing a sufficiently large cross sectional area of the second arm 111c.

[0030] Other portions of the inductor 101 according to the second embodiment, e.g., the configuration where the second block 112 itself forms the second core part which makes a pair with the first core part 111a and the configuration where the core 110 is formed of the first block 111 configured such that the first to third arms 111b to 111d protrude from the first core part 111a and the second block 112 configured not to have an arm (i.e., to have substantially the same shape as the first core part 111a), are the same as those of the first embodiment of the invention. Air gaps G_A are provided for the first arm 111b and the third arm 111d around which the windings 121 and 122 are wound, respectively. On the other hand, as in the case of the first embodiment, no gap is provided for the second arm 111c on which the windings 121 and 122 are not provided (i.e., the second block 112 and the second arm 111c closely contact with each other).

[0031] As in the case of the first embodiment, terminals

of the first winding 121 and the second winding 122 situated closely to one of the core parts may be connected to a common lead wire for the first winding 121 and the second winding 122, the other terminals situated closely to the other of the core parts may be connected to separate lead wires, and the direction in which the first winding 121 is wound may be opposite to the direction in which the second winding 122 is wound. In such a configuration, as in the case of the first embodiment, the current flows between the common lead wire and the separate lead wires, and the magnetic flux by the first winding 121 and the magnetic flux by the second winding 122 cancel with each other in the second arm 111c. Therefore, the inductor 101 is able to achieve the performance equivalent to two inductors although the inductor 101 is formed as a compact inductor whose second arm 111c has a small cross sectional area.

[0032] In the above described first and second embodiments according to the invention, windings are wound around outer two arms of the three arms of a core arranged in a line. However, the invention is not limited to such a configuration. Fig. 5 is a side view generally illustrating an inductor according to a third embodiment of the invention. An inductor 201 shown in Fig. 5 is configured such that a core 210 has a pair of upper and lower base parts (a first core part 211a included in a lower first block 211 and an upper second block 212 making the pair with the first core part 211a) and a first arm 211b, a second arm 211c, a third arm 211d and a fourth arm 211e arranged in a line between the base parts, and a first winding 221 and a second winding 222 are wound around the second arm 211c and the third arm 211d arranged inside. In this configuration, both of the magnetic fluxes B11 and B12 generated by the first winding 121 and the second winding 222 penetrate through the first arm 211b and the fourth arm 211e arranged outside. Therefore, the first arm 211b and the fourth arm 211e arranged outside serve as common arms used by both of the first winding 221 and the second winding 222.

[0033] As shown in Fig. 5, as in the case of the first embodiment, in the inductor 201 according to the embodiment, terminals of the first winding 221 and the second winding 222 on one side (the upper side in the drawing) are connected to a common lead wire 223, and the other terminals are connected to separate lead wires 221a and 222a. Furthermore, as in the case of the first embodiment, the directions in which the first winding 221 and the second winding 222 are wound are opposite to each other. Therefore, when the current flows between the common lead wire 223 and the separate lead wires 221a and 222a, the magnetic flux B11 by the first winding 221 and the magnetic flux B12 by the second winding 222 become opposite in direction with respect to each other and cancel with each other in each of the first arm 211b and the fourth arm 211e. As a result, the magnetic fluxes penetrating the first arm 211b and the fourth arm 211e become small. Accordingly, the cross sectional areas of the first arm 211b and the fourth arm 211e may

be sufficiently smaller than those of the second arm 211c and the third arm 211d.

[0034] In the inductor 201 according to the embodiment, the first to fourth arms 211b to 211e are also formed integrally with the first core part 211a of the first block 211, and the air gaps G_A are formed between the second block 212 and the second and third arms 211c and 211d around which the windings 221 and 222 are wound. On the other hand, no gap is formed between the second block 212 and the first and fourth arms 211b and 211e around which the windings 221 and 222 are not provided (i.e., the first arm 211b and the fourth arm 211e closely contact the second block 212).

[0035] Although, in the above described configuration, the arms of the core are arranged in a line, the invention is not limited to such a configuration. Fig. 6 is a perspective view of an inductor according to a fourth embodiment of the invention. An inductor 301 shown in Fig. 6 has a pair of upper and lower base parts (a first core part 311a included in a lower first block 311 and an upper second block 312 forming a second core part which makes a pair with the first core part 311). Furthermore, each of the first core part 311a and the second block 312 is formed to have a shape of a triangular plate. At positions defined by connecting corners of the first core part 311a and the second block 312, three column-like arms including a first arm 311b, a second arm 311c and a third arm 311d are provided. A first winding 321 and a second winding 322 are wound around the first arm 311b and the second arm 311c, respectively. In this configuration, both of the magnetic fluxes generated by the first winding 321 and the second winding 322 penetrate the third arm 311d.

[0036] As in the case of the first embodiment, terminals of the first winding 321 and the second winding 322 situated closely to one of the cores may be connected to a common lead wire of the first winding 321 and the second winding 322, the other terminals of the first winding 321 and the second winding 322 situated closely to the other of the cores may be connected to separate lead wires, and the direction in which the first winding 321 is wound and the direction in which the second winding 322 is wound may be opposite to each other. As in the case of the first embodiment, in such a configuration, the current flows between the common lead wire and the separate lead wires, and the magnetic flux by the first winding 321 and the magnetic flux by the second winding 322 cancel with each other in the third arm 311d. Therefore, the inductor 301 is a compact inductor having the third arm 311d whose cross sectional area is small, and is able to achieve the performance equivalent to two inductors.

[0037] In this embodiment, the first to third arms 311b to 311d are also integrally formed with the first core part 311a, and the air gaps G_A are formed between the second block 312 and the first and second arms 311b and 311c around which the windings 321 and 322 are respectively wound. On the other hand, no gap is formed for the third arm 311d around which the windings 321 and 322 are not wound (i.e., the third arm 311d closely contacts

with the second block 312).

[0038] The inductors according to the above explained first to fourth embodiments of the invention are suitable for the two-phase type interleave PFC circuit shown in Fig. 11 in which phases the pulses applied to the gates of the plurality of MOS transistors are shifted by 180° with respect to each other. However, the inductor according to the invention can also be applied to interleave PFC circuits other than the two-phase type. An inductor according to a fifth embodiment described below is configured to be suitable for a four-phase type interleave circuit in which phases of pulses inputted to MOS transistors respectively provided for four windings are shifted by 90° with respect to each other.

[0039] Fig. 7 is a perspective view illustrating an inductor according to the fifth embodiment. A core 410 of an inductor 401 according to the embodiment has a pair of upper and lower base parts (a first core part 411a included in a lower first block 411 and an upper second block 412 which by itself makes a pair with the first core part 411a). Each of the first core part 411a and the second block 412 is formed to be a rectangular plate, and, at positions defined by connecting the corners of the base parts, four column-like arms including a first arm 411b, a second arm 411c, a third arm 411d and a fourth arm 411e are provided, and a fifth arm 411f is provided at the center of the rectangle. The first to fifth arms 411b to 411f are formed integrally with the first core part 411a. Furthermore, the inductor 401 according to the embodiment has a first winding 421, a second winding 422, a third winding 423 and a fourth winding 424, and these windings are wound around the first arm 411b, the second arm 411c, the third arm 411d and the fourth arm 411e, respectively.

[0040] When the current flows through the first winding 421, the second winding 422, the third winding 423 and the fourth winding 424, the magnetic fluxes are caused by the first to fourth windings 421 to 424 in the core 410. Each of these magnetic fluxes penetrates through the fifth arm 411f.

[0041] In the inductor 401 according to the embodiment, the directions in which the first to fourth windings 421 to 424 are wound are set so that the magnetic fluxes caused by the windings in the fifth arm 411f cancel with each other. Specifically, terminals of the first to fourth windings 421 to 424 situated closely to one of the cores may be connected to a common lead wire of the first to fourth windings 421 to 424, the other terminals of the first to fourth windings 421 to 424 situated closely to the other of the cores may be connected to separate lead wires, and the direction in which the first winding 421 and the third winding 423 are wound may be opposite to the direction in which the second winding 422 and the fourth winding 424 are wound. In such a configuration, as in the case of the first embodiment, the current flows between the common lead wire and the separate lead wires, and the magnetic fluxes caused by the first to fourth windings 421 to 424 cancel with each other in the fifth arm 411f.

As a result, the magnitude of the magnetic flux penetrating the fifth arm 411f becomes small. Accordingly, the cross sectional area of the fifth arm 411f may be sufficiently smaller than the sum of the cross sectional areas of the first to fourth arms 411b to 411e.

[0042] As described above, in this embodiment, the first to fourth windings 421 to 424 share a part of the core 410 (i.e., the fifth arm 411f in this embodiment). Therefore, as compared to a configuration where windings are wound around separate cores, it becomes possible to considerably decrease the volume and the installation area of the inductor. As a result, by employing the inductor 401 according to the embodiment in the interleaved PFC circuit, a voltage conversion circuit which is compact in size and whose ripple is small can be realized. Furthermore, in this embodiment, the four windings of the inductor are attached to the outer arms of the core, it becomes possible to effectively release heat to the outside without letting heat generated by the windings stay in the central part.

[0043] In the inductor 401 according to the embodiment, the air gaps G_A are also formed between the second block 412 and the first to fourth arms 411b to 411e. The air gap G_A prevents occurrence of the magnetic saturation in each of the first to fourth arms 411b to 411e.

[0044] No gap G_A is formed between the fifth arm 411f and the second block 412 (i.e., the fifth arm 411f closely contacts with the second block 412). Therefore, the magnetic resistance of the path between the fifth arm 411f and each of the other arms is sufficiently smaller than the magnetic resistances of the paths among the first to fourth arms 411b to 411f. As a result, almost all of the magnetic fluxes generated by the first to fourth windings 421 to 424 penetrate through the fifth arm 411f. Therefore, it becomes possible to prevent occurrence of a problem that, by a magnetic flux caused by one of the endings, electromagnetic induction is caused in another winding and thereby a noise is caused on the output.

[0045] In this embodiment, the first to fourth arms 411b to 411e are arranged at the positions where the corners of the first core part 411 and the second block 412 both of which have the rectangular shape are connected. However, the invention is not limited to such a configuration. For example, arms for windings may be arranged at positions where corners of cores each having a polygonal shape, such as a rhombic shape or a right-angle trapezoid, are connected with each other.

[0046] In the above described first to fifth embodiments according to the invention, arms for which windings are provided are integrally formed with an arm for which a winding is not provided (i.e., an arm which shares magnetic flux loops with all the arms for which the above described windings are provided). However, the invention is not limited to the above described configuration. An inductor according to a sixth embodiment described below is configured such that an arm for which a winding is provided is separate from the other arm.

[0047] Fig. 8 is a perspective view of an inductor ac-

cording to the embodiment. Fig. 9 is a perspective view of a core of the inductor according to the embodiment. Fig. 10 is an exploded perspective view of the inductor according to the embodiment. As shown in Fig. 8, the inductor 501 according to the embodiment includes a core 510, a first winding 521 and a second winding 522. In Figs. 8 to 10, the first and second windings 521 and 522 are shown by a dashed line.

[0048] As shown in Fig. 9, the core 510 of the inductor 501 according to the embodiment includes a first block 5111 and a second block 512 respectively having a first core part 511a and a second core part 512a each having a form of a hexagonal plate. The core 510 includes a first arm 513, a second arm 514, a third arm 515 and a fourth arm 516. The first arm 513 and the fourth arm 516 are arranged to connect the two opposing corners of the hexagonal first core part 511a with the two opposing corners of the hexagonal second core part 512a, and a first winding 521 and a second winding 522 are arranged around the first arm 513 and the fourth arm 516, respectively. As shown in Figs 8 and 10, the first and the second windings 521 and 522 are attached around the first and fourth arms 513 and 516 via bobbins 531 and 532, respectively.

[0049] Each of the first arm 513 and the fourth arm 516 is a column-like member, and is provided separately from the first and second blocks 511 and 512. As shown in Figs. 9 and 10, at the both ends of each of the first arm 513 and the fourth arm 516, gap members G_p each of which is a resin member formed in a circular plate are attached, so that the first arm 513 and the fourth arm 516 do not directly contact with the first block 511 and the second block 512.

[0050] On the other hand, the second arm 514 is divided into two pieces including divided arm parts 514a and 514b. One divided arm part 514a is formed integrally with the first core part 511a, and the other divided arm part 514b is formed integrally with the second core part 512a. Similarly, the third arm 515 is divided into two pieces including divided arm parts 515a and 515b (see Fig. 10). One divided arm part 515a is formed integrally with the first core part 511a, and the other divided arm part 515b is formed integrally with the second core part 512a. Thus, the first core part 511a and the divided arm parts 514a and 515a form the first block 511, and the second core part 512a and the divided arm parts 514b and 515b form the second block 512. As shown in Figs. 8 and 9, when the inductor 501 is assembled, the bobbins 531 and 532 are accommodated between the first block 511 and the second block 512, and the divided arm parts 514a and 514b closely contact with each other in a space between the bobbins 531 and 532. Similarly, when the inductor 501 is assembled, the divided arm parts 515a and 515b closely contact with each other in a space between the bobbins 531 and 532 (not shown).

[0051] As described above, the gap members G_p are provided between the first and fourth arms 513 and 516 and the first and second blocks 511 and 512, and no gap is formed for the second and third arms 514 and 515

connecting the first block 511 with the second block 512. Therefore, the magnetic resistances of the first arm 513 and the fourth arm 516 are larger than the magnetic resistances of the second arm 514 and the third arm 515. In particular, in this embodiment, each of the first arm 513 and the fourth arm 516 is a dust core, and each of the first block 511 and the second block 512 is formed of a ferrite core. Such a configuration causes the magnetic resistances of the first arm 513 and the fourth arm 516 to be further larger than the magnetic resistances of the second arm 514 and the third arm 515. As a result, occurrence of the magnetic saturation in each of the first arm 513 and the fourth arm 516 is prevented. Furthermore, since the magnetic resistances of the first arm 513 and the fourth arm 516 are large, the magnet flux generated by the first winding 521 in the first arm 513 does not proceed to the fourth arm 516 and the magnetic flux caused by the second winding 522 in the fourth arm 516 does not proceed to the first arm 513. Almost all of these magnetic fluxes proceed to the second arm 514 and the third arm 515.

[0052] As in the case of the other embodiments, terminals of the first winding 521 and the second winding 522 situated closely to one of the cores may be connected to a common lead wire of the first winding 521 and the second winding 522, the other terminals of the first winding 521 and the second winding 522 situated closely to the other of the cores may be connected to separate lead wires, and the direction in which the first winding 521 is wound may be opposite to the direction in which the second winding 522 is wound. In such a configuration, the current flows through the position between the common lead wire and the separate lead wires, and the magnetic flux caused by the first winding 521 and the magnetic flux caused by the second winding 522 cancel with each other in each of the second arm 514 and the third arm 515. Therefore, the inductor 501 is able to achieve the performance equivalent to two inductors although the inductor 501 is formed as a compact inductor having the second arm 514 and the third arm 515 with small sectional areas.

[0053] As shown in Fig. 9, as in the case of the second embodiment (Fig. 4), the inductor 501 according to the embodiment is configured such that surfaces of the second arm 514 and the third arm 515 situated closely to the first winding 521 and the second winding 522 are formed to be concave surfaces formed along outer circumferential surfaces of the windings. As a result, the second arm 514 and the third arm 515 having sufficient cross sectional areas can be obtained, and it is also possible to set the interval between the first winding 521 and the second winding 522 to be short. Therefore, as in the case of the second embodiment, it is possible to decrease the size in the width direction of the inductor 501 (i.e., the arranging direction of the first winding 521 and the second winding 522).

[0054] The foregoing is the embodiments according to the invention. The invention is not limited to the above

described configurations of the first to sixth embodiments, and inductors formed by appropriately combining configurations of the first to sixth embodiments are also be included in the invention. For example, although the inductors according to the first to fifth embodiments are configured such that the arms on which the windings are provided are integrally formed with one of the cores and the air gaps G_A are formed between the arms and the other of the cores, an inductor in which resin gap members G_P are provided between both the cores and arms on which windings are provided as shown in the sixth embodiment is also included in the invention. Alternatively, the inductor according to each of the first to fifth embodiments may be configured such that the common arm on which the winding is not provided has a pair of divided arms provided respectively for the first and second blocks, and the divided arms closely contact with each other to form a common arm.

[0055] As in the case of the first to fifth embodiments, in the inductor according to the sixth embodiment, a configuration where the first arm 513 and the fourth arm 516 are integrally formed with the first block 511 and the air gaps G_A are formed between the second block 512 and the first and fourth arms 513 and 516 is also included in the invention. In the inductor 501 according to the sixth embodiment, the entire second arm 514 and the entire third arm 515 may be integrally formed with the first block 511, and the second arm 514 and the third arm 515 may closely contact the second block 512.

[0056] The first auxiliary winding 21' and the second auxiliary winding 22' shown in Fig. 3 may be applied to the second to sixth embodiments. That is, in the second to sixth embodiments, a configuration in which auxiliary windings are respectively provided for arms on which windings are provided is also included in the invention. For example, when such a configuration is applied to the fifth embodiment, auxiliary windings may be provided respectively for the first arm 411b, the second arm 411c, the third arm 411d and the fourth arm 411e. When such a configuration is applied to the sixth embodiment, auxiliary windings may be provided respectively for the bobbins 531 and 532 or bobbins around which auxiliary windings are wound may be additionally attached around the first arm 513 and the fourth arm 516.

Claims

1. An inductor having a core and a plurality of windings, wherein the core comprises:

a plurality of arms for windings around which the plurality of windings are respectively wound;
at least one common arm which forms magnetic loops with the plurality of arms for windings, respectively; and
a pair of base parts,
wherein the plurality of arms for windings and

- the common arm are located between the pair of base parts.
2. The inductor according to claim 1, wherein the common arm is integrally formed with one of the pair of base parts and closely contacts with the other of the pair of base parts. 5
 3. The inductor according to claim 1, wherein: 10

the common arm has a first divided arm part formed integrally with one of the pair of base parts, and a second divided arm part formed integrally with the other of the pair of base parts; and 15

the first divided arm part and the second divided arm part closely contact with each other.
 4. The inductor according to claim 1, wherein magnetic resistances of the plurality of arms for windings are larger than a magnetic resistance of the common arm. 20
 5. The inductor according to claim 4, wherein the plurality of arms for windings are separately provided from each of the pair of base parts, and plate-like gap members are sandwiched between the pair of base parts and the plurality of arms for windings. 25
 6. The inductor according to claim 5, wherein the gap members are made of resin material. 30
 7. The inductor according to claim 4, wherein material forming the plurality of arms for windings has a magnetic resistance larger than a magnetic resistance of material forming the pair of base parts and the common arm. 35
 8. The inductor according to claim 7, wherein the plurality of arms for windings are dust cores, and each of the pair of base parts and the common arm is a ferrite core. 40
 9. The inductor according to claim 4, wherein: 45

the plurality of arms for windings are formed integrally with one of the pair of base parts; and

air gaps are formed between the other of the pair of base parts and the plurality of arms for windings. 50
 10. The inductor according to claim 1, wherein: 55

the number of the plurality of arms for windings is two; and
- the plurality of arms for windings and the common arm are arranged in a line such that, between the pair of base parts, the common arm is positioned between the two arms for windings.
11. The inductor according to claim 1, wherein:

the number of the at least one common arm is two; and

the plurality of arms for windings and the two common arms are arranged in a line such that, between the pair of base parts, the plurality of arms for windings are positioned between the two common arms.
 12. The inductor according to claim 1, wherein:

the pair of base parts have polygonal shapes; and

the plurality of arms for windings are provided at positions connecting corners of the pair of base parts with each other.
 13. The inductor according to claim 12, wherein:

the plurality of arms for windings are respectively provided at all the corners of the pair of base parts; and

the common arm is located at a position connecting central portions of the pair of base parts with each other.
 14. The inductor according to claim 12, wherein the common arm is provided at a position connecting outer edge parts of the pair of base parts with each other, and wherein the plurality of arms for windings are not located at the outer edge parts of the pair of base parts.
 15. The inductor according to claim 12, wherein the plurality of arms for windings are provided at opposing corner parts of the pair of base parts.
 16. The inductor according to claim 1, further comprising a plurality of auxiliary windings, wherein the plurality of auxiliary windings are respectively wound around the plurality of arms for windings.
 17. The inductor according to any of claims 1 to 16, wherein magnetic fluxes respectively generated in the common arm by the plurality of arms for windings cancel with each other.

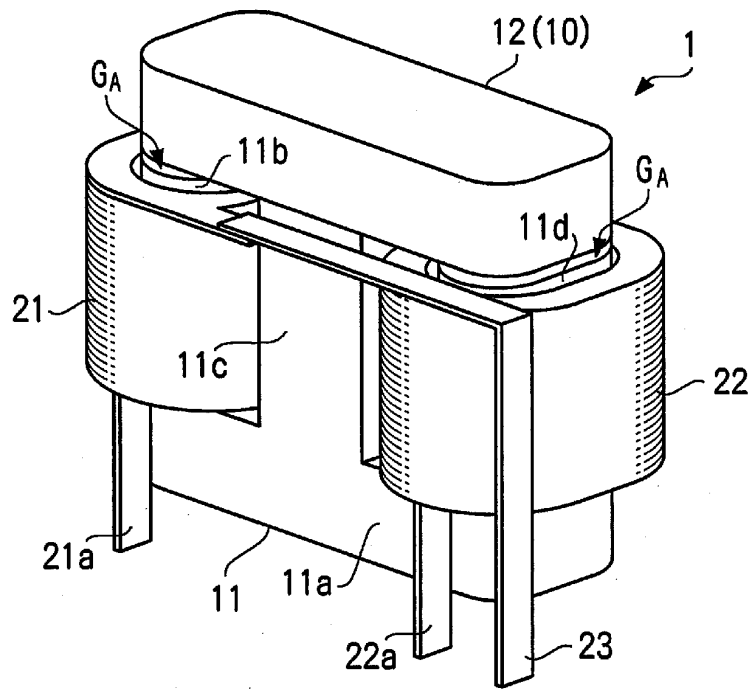


FIG. 1

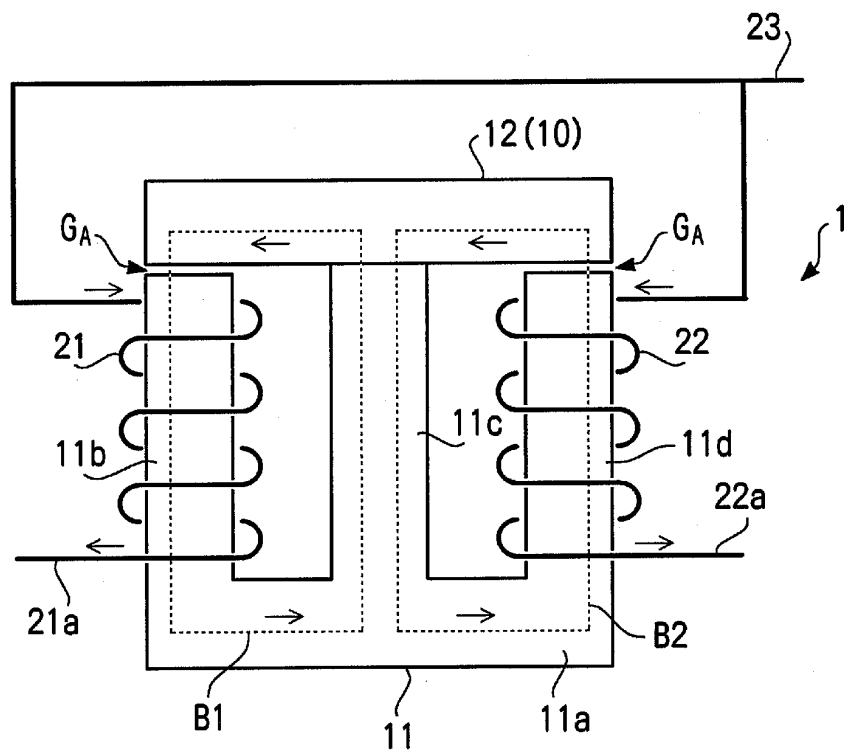


FIG. 2

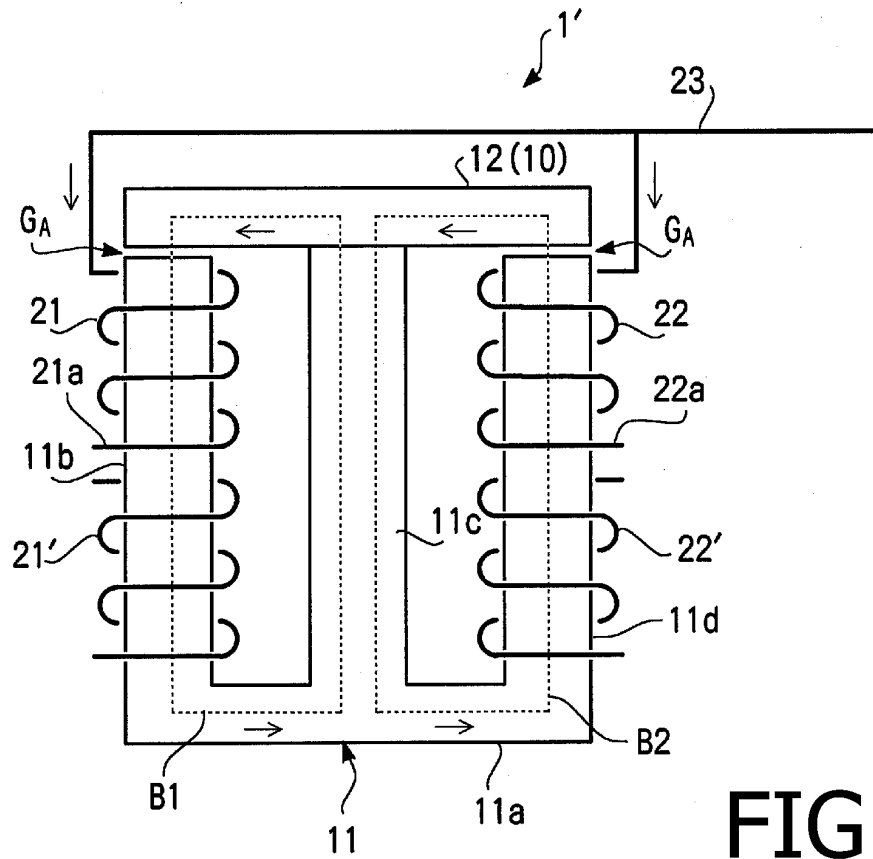


FIG. 3

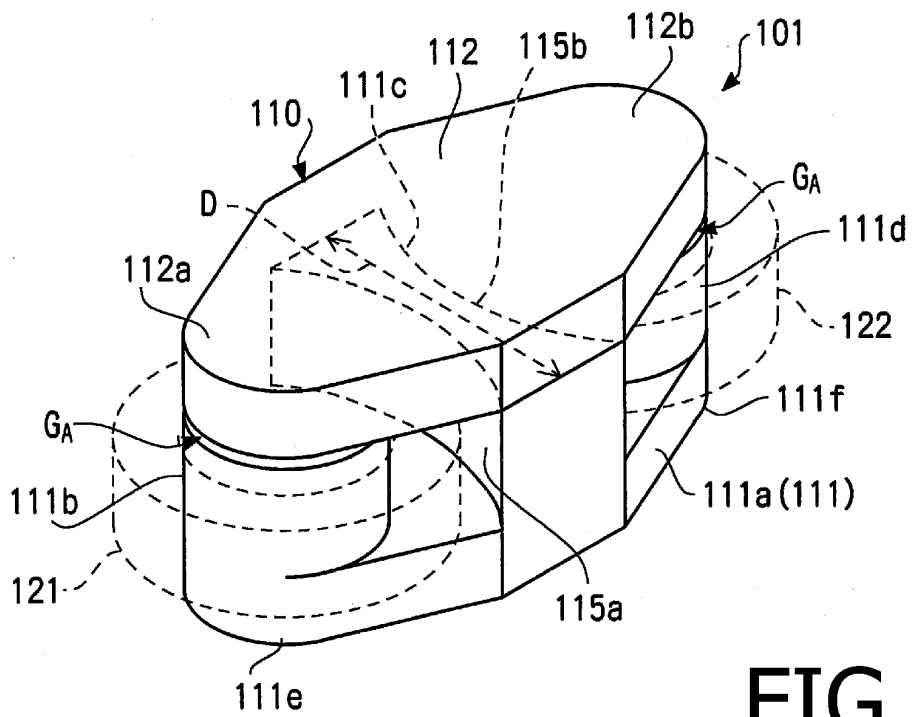


FIG. 4

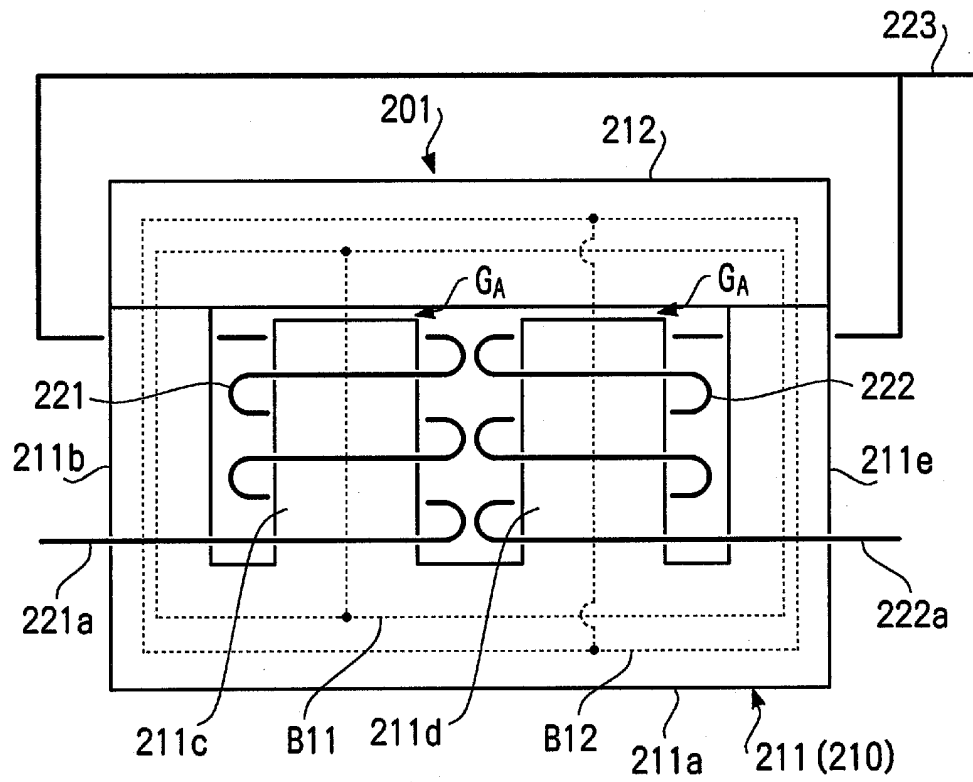


FIG. 5

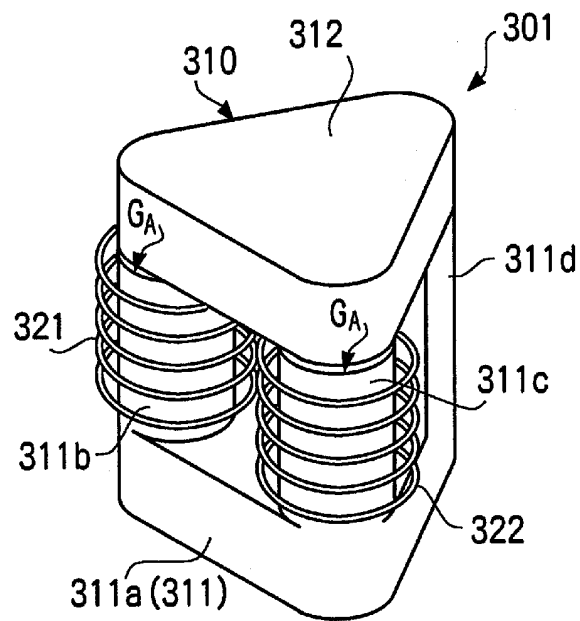


FIG. 6

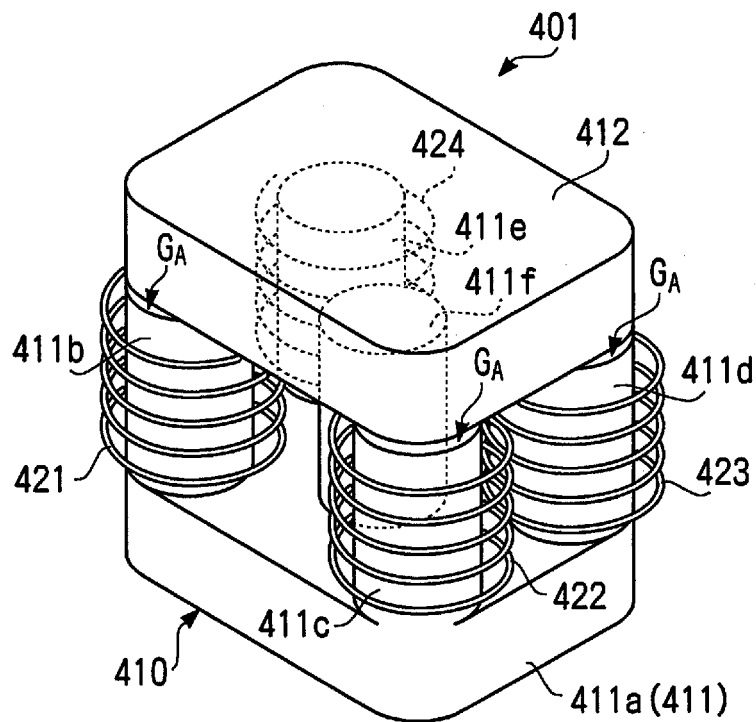


FIG. 7

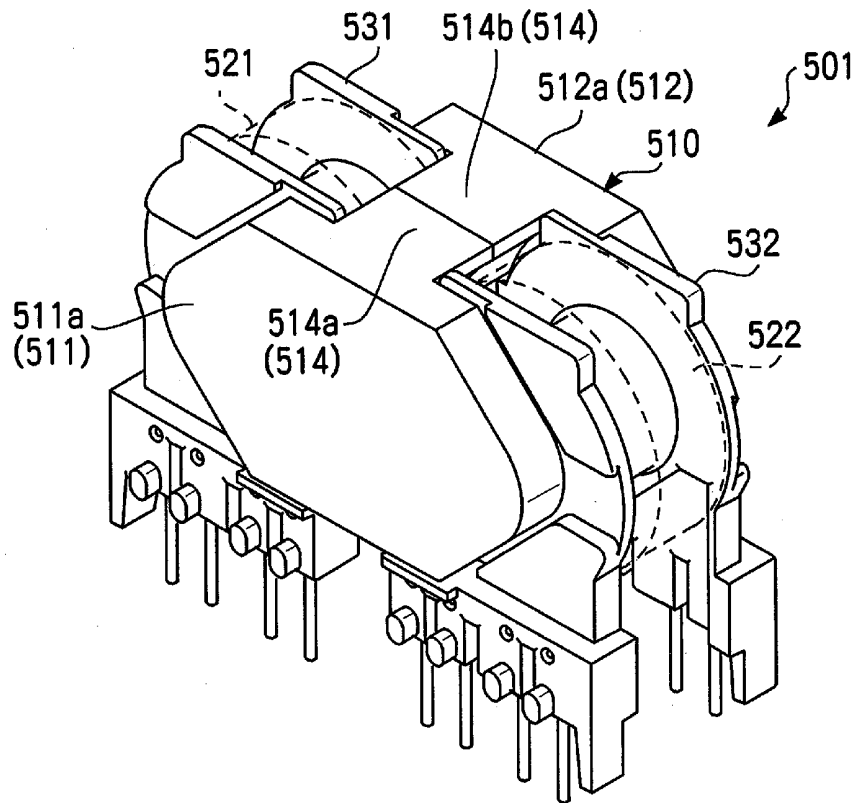


FIG. 8

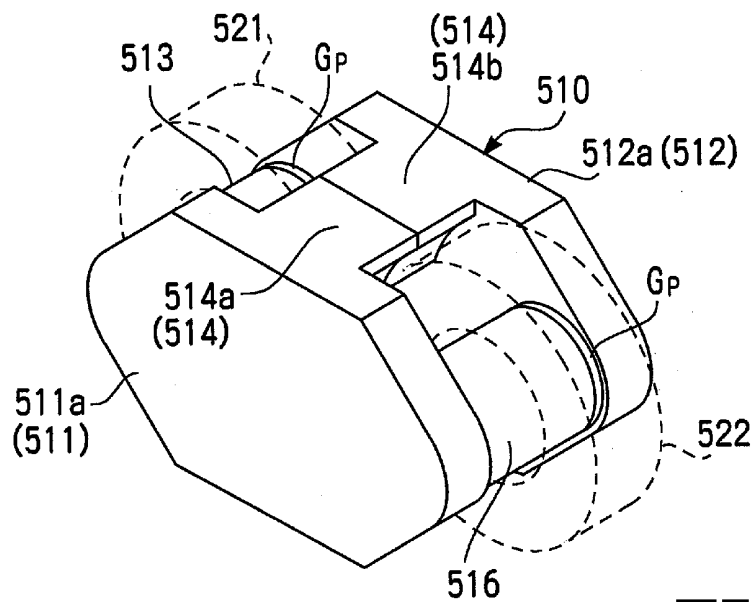


FIG. 9

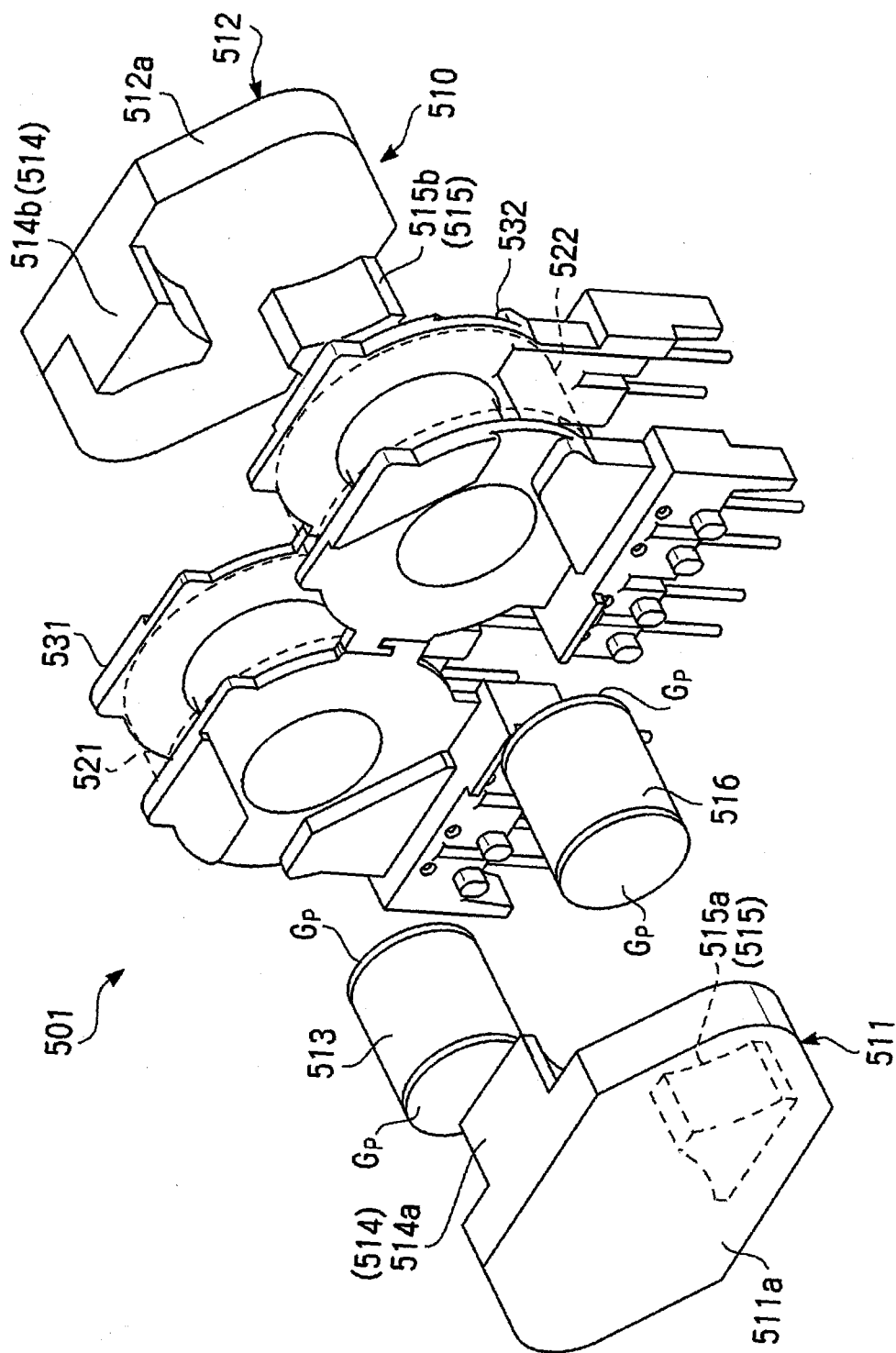


FIG. 10

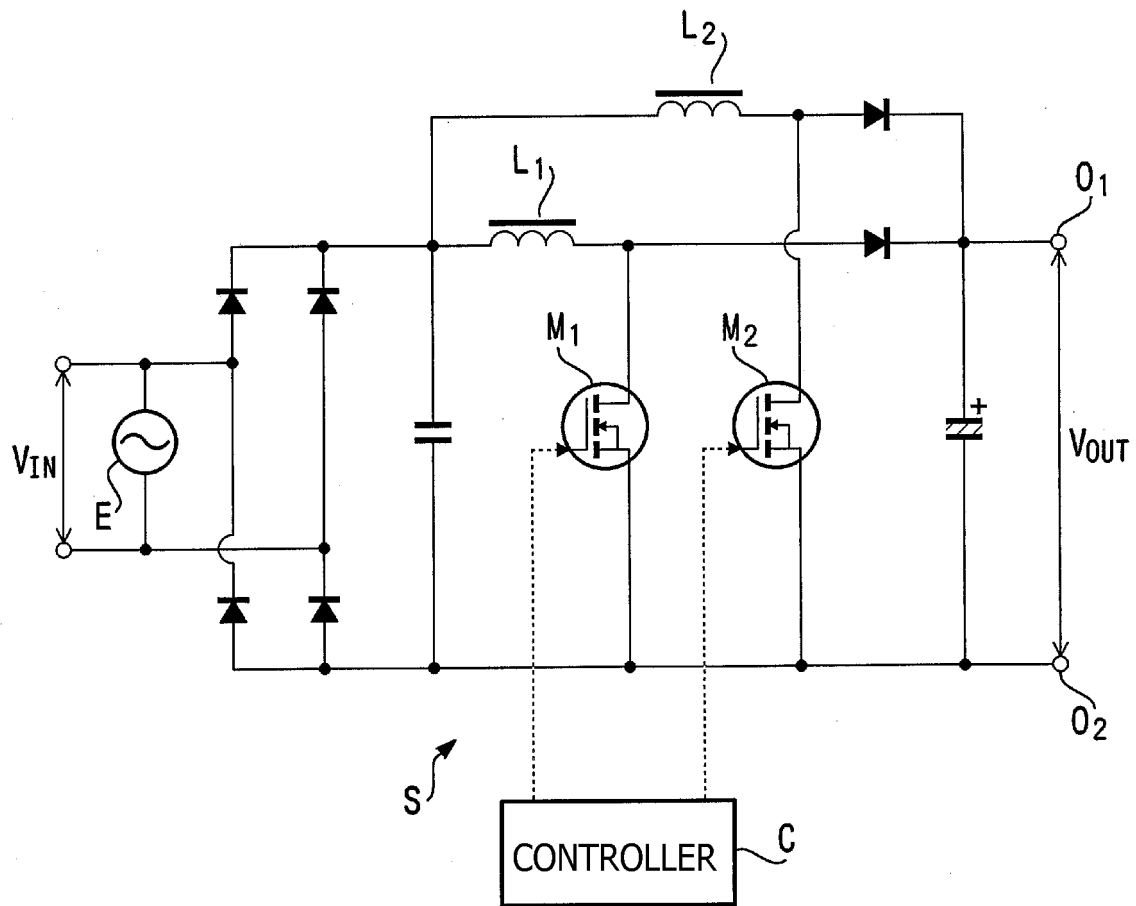


FIG. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/001082

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT, WPI, EPODOC, CNKI, induc+, coil?, winding?, core, gap, arm, column, post, pole, leg, flux

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
PX	CN201508741U (DELTA ELECTRONICS INC) 16. Jun. 2010 (16.06.2010) Paragraph 0030-0036 in the description, figs. 1-6	1-3, 10
X	CN201160024Y (TDG TECHNOLOGY CO LTD) 03. Dec. 2008 (03.12.2008) Page 4 line 17 to page 5 line 9 in the description, figs. 1-8	1-4, 7-9, 11, 16
Y		5-6, 12-15
X	JP9-237722A (TAMURA SEISAKUSHO KK) 09. Sep. 1997 (09.09.1997) Paragraph 0010-0014 in the description, figs. 1, 4	1, 10, 17

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search 03. Sep. 2010 (03.09.2010)	Date of mailing of the international search report 30 Sep. 2010 (30.09.2010)
Name and mailing address of the ISA/CN The State Intellectual Property Office, the P.R.China 6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China 100088 Facsimile No. 86-10-62019451	Authorized officer YIN, Lumin Telephone No. (86-10)62411544

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/001082

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	CN201004357Y (Zhuang Yifang) 09. Jan. 2008 (09.01.2008) Page 5 lines 7-14 in the description, figs. 7-8	5-6
Y	JP2001-230120A (HITACHI FERRITE ELECT LTD) 24. Aug. 2001 (24.08.2001) Paragraph 0012-0013 in the description, figs. 1-3	12-15

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2010/001082

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN201508741U	16.06.2010	NONE	
CN201160024Y	03.12.2008	NONE	
JP9-237722A	09.09.1997	JP2729937B2	18.03.1998
CN201004357Y	09.01.2008	NONE	
JP2001-230120A	24.08.2001	NONE	

Form PCT/ISA/210 (patent family annex) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2010/001082

A. CLASSIFICATION OF SUBJECT MATTER

H01F 17/04 (2006.01) i

H01F 27/24 (2006.01) n

REFERENCES CITED IN THE DESCRIPTION

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