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(54) INDUCTOR

(57) The embodiments of the present application relate to the technical field of inductors. Provided is an inductor, comprising: a plurality of coils and a magnetic core. The magnetic core comprises: an upper bottom plate and a lower bottom plate, which are arranged in parallel and opposite each other; a plurality of winding columns, which are located between the upper bottom plate and the lower bottom plate, and around which the plurality of coils are wound; and at least one non-winding column, which is arranged between the upper bottom plate and the lower bottom plate, wherein the numbers of turns of coils on at least two of the winding columns are different, and the directions of currents in the coils are opposite; and there are air gaps in the at least two winding columns, around which the coils are wound for different numbers of turns, and the sizes of the air gaps in the winding columns are different. By means of the inductor in the embodiments, an inductor having different proportions of magnetic loss and copper loss can be configured according to different heat dissipation conditions of the environment in which the inductor is located, thereby realizing the differentiated design of an inductor.

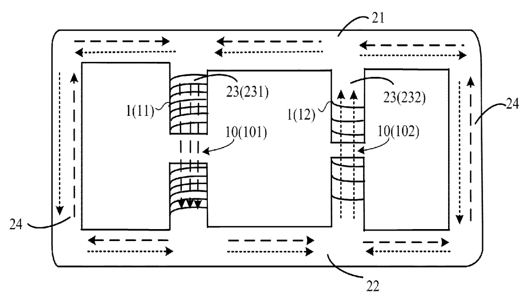

Fig. 1

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Description

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] The present application refers to Chinese Application No. 2021107664037 entitled "Inductor", filed on July 7th, 2021, which is entirely incorporated herein by reference.

TECHNICAL FIELD

[0002] Embodiments of the present application relate to the technical field of inductors, in particular to an inductor.

BACKGROUND

[0003] In the technical field of inductors, especially a high-power converter adopts an interleaving technology, which may effectively reduce a current ripple and achieve a higher power density and efficiency, so the number of magnetic parts required will be inevitably increased, if discrete inductors are still used, a volume is greatly increased, and a larger space is occupied, so an integrated structure is adopted, which may effectively reduce the volume of a magnetic core, and improve efficiency. However, existing integrated inductors do not provide solutions for the problems such as uneven heat dissipation and efficiency of the actual magnetic parts.

SUMMARY

[0004] An embodiment of the present application mainly aims to propose an inductor, and an inductance having different proportions of magnetic losses and copper losses may be set according to different heat dissipation conditions of the environment in which the inductor is located, thereby realizing the differentiated design of the inductor.

[0005] In order to achieve the above aim, an embodiment of the present application provides an inductor, including: a plurality of coils and a magnetic core; the magnetic core includes: an upper bottom plate and a lower bottom plate, which are arranged in parallel up and down, a plurality of winding columns, which are located between the upper bottom plate and the lower bottom plate, and around which the plurality of coils are wound, and at least one non-winding column, which is arranged between the upper bottom plate and the lower bottom plate; and the numbers of turns of coils on at least two of the winding columns are different, directions of currents in the coils are opposite, there are air gaps in the at least two winding columns, around which the coils are wound for different numbers of turns, and the sizes of the air gaps in the winding columns are different.

[0006] The inductor proposed by the present application includes the plurality of coils and the magnetic core. The magnetic core includes: the upper bottom plate and the lower bottom plate, which are arranged in parallel up and down, the plurality of winding columns, which are located between the upper bottom plate and the lower bottom plate, and around which the plurality of coils are wound, and at least one non-winding column, which is arranged between the upper bottom plate and the lower bottom plate, wherein the numbers of turns of coils on at least two winding columns are different, and the directions of the currents in the coils are opposite; and there are air gaps in the at least two winding columns, around which the coils are wound for different numbers of turns, and the sizes of the air gaps in the winding columns are different. Compared with an original inductor with the same number of turns and the same air gaps, the present scheme may adjust the proportions of the magnetic losses and the copper losses by arranging at least two winding coils with different numbers of turns and different sizes of the air gaps, so that the inductor with different turn ratios may be arranged according to different heat dissipation conditions of the environment, thereby realizing the differentiated design.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] One or more embodiments are exemplarily illustrated through pictures in corresponding accompanying drawings, and these exemplifications do not constitute a limitation to the embodiments.

Fig. 1 is a schematic structural diagram of an inductor in an instance according to the present application;
Fig. 2 is a schematic structural diagram of an inductor according to an existing example;
Fig. 3 is a distribution diagram of magnetic core losses of two inductors with different turn ratios according to the present application; and
Fig. 4 is a schematic structural diagram of an inductor in another instance according to the present application.

DETAILED DESCRIPTION

[0008] To make the objectives, technical solutions and advantages of the present application clearer, embodiments of the present application will be described in detail below in combination with the accompanying drawings. However, those ordinarily skilled in the art may understand that in the embodiments of the present application, in order to make a reader better understand the present application, many technical details are proposed. Yet, even without these technical details and various variations and modifications based on the following embodiments, it may also realize the technical solution of protection claimed in the present application. The following embodiments are divided for convenience of description and shall not constitute any limitation to the specific implementation of the present application. The embodiments may be combined and referenced to each other without contradiction.

[0009] In the technical field of inductors, especially a high-power converter adopts an interleaving technology, which may effectively reduce a current ripple and achieve a higher power density and efficiency, so the number of magnetic parts required will be inevitably increased, if discrete inductors are still used, a volume is greatly increased, and a larger space is occupied, so an integrated structure is adopted, which may effectively reduce the volume of a magnetic core, and improve efficiency. The following contents of the present embodiment are mainly aimed at the problems such as uneven heat dissipation and efficiency of actual magnetic parts, and differential design is proposed by combining the copper losses and magnetic losses of the magnetic parts.

[0010] Referring to Fig. 1, in an embodiment, an inductor includes: a plurality of coils 1 and a magnetic core 2; and the magnetic core 2 includes: an upper bottom plate 21 and a lower bottom plate 22, which are arranged in parallel up and down, a plurality of winding columns 23, which are located between the upper bottom plate 21 and the lower bottom plate 22, and around which the plurality of coils 1 are wound, and at least one non-winding column 24, which is arranged between the upper bottom plate 21 and the lower bottom plate 22. The numbers of turns of the coils 1 on at least two winding columns 23 are different, directions of currents in the coils 1 are opposite, there are air gaps 10 in the at least two winding columns 23, around which the coils are wound for different numbers of turns, and the sizes of the air gaps 10 in the winding columns 23 are different.

[0011] Optionally, the air gaps 10 are located at positions of the winding columns 23 away from the upper bottom plate 21 and the lower bottom plate 22, and each winding column 23 is connected with the upper bottom plate 21 and the lower bottom plate 22. In other words, the air gaps 10 are located at positions of middle regions of the winding columns 23, and each winding column 23 is connected with the upper bottom plate 21 and the lower bottom plate 22. The air gaps 10 are single-segment air gaps 10 or multi-segment air gaps 10.

[0012] In the embodiment, the magnetic core 2 includes the non-winding column 24, the winding columns 23, the upper bottom plate 21 and the lower bottom plate 22, and a material of the magnetic core 2 includes ferrite, an amorphous body, a magnetic powder core or silicon steel. In actual application, materials of the non-winding column 24, the winding columns 23, the upper bottom plate 21 and the lower bottom plate 22 may be the same or different, the upper bottom plate 21 and the lower bottom plate 22 may be in a plate shape, two ends of each winding column 23 in the plurality of winding columns 23 are connected to the upper bottom plate 21 and the lower bottom plate 22 respectively, and two ends of at least one non-winding column 24 are connected to the upper bottom plate 21 and the lower bottom plate 22 respectively.

[0013] Optionally, the non-winding column 24, the winding columns 23, the upper bottom plate 21 and the lower bottom plate 22 are integrally formed.

[0014] Optionally, the upper bottom plate 21 and the lower bottom plate 22 may adopt a hexagonal structure or other polygonal structures, and the winding columns 23 and the non-winding column 24 may be in an elliptic, circular, or polygonal columnar shape.

[0015] The inventor finds by research that when the number of turns of the coil 1 on a certain winding column 23 is increased, and the air gap 10 is enlarged, a copper loss of the whole inductor may be increased, and a magnetic loss is reduced; and when the number of turns of the coil 1 on a certain winding column 23 is reduced, and the air gap 10 is decreased, the copper loss of the whole inductor may be reduced, and the magnetic loss is increased. The actual inductor is applied to a communication power supply or other switching power supply, and whether it is a natural heat dissipation or air-cooled heat dissipation environment, the inductor has an air duct near surface and an air duct leeward surface, or is near a heat source or away from the heat source. In this way, the differential optimal design may be carried out according to the actual situation. For example, in the case of the air duct near surface and a good heat dissipation effect, the number of turns of the coils 1 on the winding columns 23 may be appropriately increased, and the air gaps 10 may be enlarged to reduce the magnetic loss. Or, in the case of the air duct far surface and a poor heat dissipation effect, the number of winding turns on the winding columns 23 may be reduced to reduce the copper loss. Thus, differentiated design may be carried out for heat dissipation and efficiency consideration, the magnetic loss and the copper loss are compromised, and the utilization rate of the inductor is improved while the heat dissipation problem is taken into account.

[0016] Based on the above principle, the numbers of turns of the coils 1 on at least two winding columns 23 in the inductor proposed in the present embodiment are different, and the directions of currents in the coils 1 are opposite; and there are air gaps 10 in the at least two winding columns 23, around which the coils are wound for different numbers of turns, and the sizes of the air gaps 10 in the winding columns 23 are different.

[0017] The numbers of turns of the coils 1 on at least two winding columns 23 are different, and the directions of the currents in the coils 1 are opposite, so that magnetic fluxes on the non-winding column 24 may be mutually attenuated. Based on this, a cross sectional area of the non-winding column 24 may be smaller than that of the winding columns 23, and reducing the volume of the non-winding column 24 can not only reduce the magnetic loss of the magnetic core 2, but also improve an integration degree of the inductor and reduce the volume of the inductor.

[0018] In order to meet design requirements of power electronic products, it is usually necessary to polish the magnetic core 2 to form the air gaps 10 to adjust the inductance capacitance of the product. The effect of the air gaps 10 is to reduce the permeability so that coil characteristics are less dependent on the initial permeability of the material of the magnet core 2. The air gaps 10 can avoid the phenomenon of magnetic saturation under an alternating-current large signal or direct-current bias, and the inductance capacitance is better controlled. However, in a case that the air gaps 10 reduce the permeability, more turns of coils 1 are required, a relevant copper loss is also increased, so appropriate compromises are needed. In the present embodiment, since the numbers of turns of the coils 1 on at least two winding columns 23 are different, the sizes of the air gaps 10 in the two winding columns 23 are also different in order to make inductance values formed by the coils 1 on the two winding columns 23 be similar. There is one or more air gaps 10 in each winding column 23 in at least two winding columns 23, and sizes of the air gaps 10 in the two winding columns 23 with different turns of coils 1 are also different. It is worth noting that in order to illustrate the technical principle in present embodiment by using a control variable method, the magnitude of a current introduced in each coil 1 in the present embodiment is the same.

[0019] In this scheme, by arranging at least two winding coils 1 with different numbers of turns and different sizes of air gaps 10, the proportion of the magnetic loss and the copper loss may be adjusted compared with original inductors with the same number of turns and the same air gaps 10, so that in actual use, the inductors with different turn ratios may be arranged according to different heat dissipation conditions of the environment, and differentiated design is realized.

[0020] The inductor in the present embodiment is illustrated in detail in combination with a specific example:

In one example, as shown in Fig. 1, the number of the winding columns 23 is two, the numbers of turns of the coils 1 on the two winding columns 23 are different, the two winding columns 23 are a first winding column 231 and a second winding column 232; and the number of turns of the coil 1 wound on the first winding column 231 is greater than the number of turns of the coil 1 wound on the second winding column 232, and the air gap 10 in the second winding column 232 is smaller than the air gap 10 in the first winding column 231.

[0021] Specifically, the inductor is provided in the present embodiment, the magnetic core 2 includes the upper bottom plate 21, the lower bottom plate 22, two winding columns 23, and two non-winding columns 24. The two winding columns 23 are the first winding column 231 and the second winding column 232 respectively, a first coil 11 is on the first winding column 231, a second coil 12 is on the second winding column 232, and the number of turns of the first coil 11 is greater than the number of turns of the second coil 12, so that magnetic field strength on the first winding column 231 may be increased. The first winding column 231 includes a first air gap 101, and the second winding column 232 includes a second air gap 102. The first air gap 101 is greater than the second air gap 102, so that magnetoresistance on the first winding column 231 may be increased. Under a combined action of the number of turns of the first coil 11 on the first winding column 231 and the first air gap 101, a value of a first inductance formed by the first winding column 231 and the first coil 11 is close to a value of a second inductance formed by the second winding column 232 and the second coil 12.

[0022] In some examples, the first winding column 231 and the coil 1 form the first inductance, the second winding column 232 and the coil 1 form the second inductance, and magnitudes of values of the first and second inductances are the same.

[0023] The inductor shown in Fig. 2 is provided in the present embodiment, the number of turns of the first coil 11 on the first winding column 231 is the same as the number of turns of the second coil 12 on the second winding column 232, and the sizes of the air gaps 10 in the first winding column 231 and the second winding column 232 are the same. It is supposed that the turn ratio of the first coil 11 to the second coil 12 in the inductor shown in Fig. 2 is 3:3, while the turn ratio of the first coil 11 to the second coil 12 in the inductor shown in Fig. 1 in the present embodiment is 5:3. The simulating calculation of losses of magnetic cores 2 of the inductor under two turn ratios is shown in Fig. 3, it may be seen that in the inductor with the same turn ratio shown in Fig. 2, the loss of the magnetic core 2 is reduced significantly after increasing the number of turns on a certain winding column 23 and increasing the air gap 10. The copper loss is power consumed on a resistance of a primary secondary winding when the current passes through the primary secondary winding of a transformer, and it may be determined that the copper loss is increased after the number of turns on a certain winding column 23 is increased and the air gap 10 is enlarged. This also proves correctness of the above theory studied by the inventor on the other hand.

[0024] Optionally, the number of the winding columns 23 is two, and the two winding columns 23 and the two non-winding columns 24 are arranged in a row, and a specific arranging mode of the winding columns 23 and non-winding columns 24 is given.

[0025] In another example, as shown in Fig. 4, the number of the non-winding columns 24 is two, and the plurality of winding columns 23 are located between the two non-winding columns 24; and the coils 1 on the plurality of the winding columns 23 are arranged in such a way that the magnetic fluxes formed in two non-winding columns 24 cancel each other. In other words, the magnetic fluxes formed by the coils 1 on the plurality of winding columns 23 on the two non-winding columns 24 may cancel each other, so that the cross-sectional area of the non-winding columns 24 may be less than that of the winding columns 23, and reducing the volume of the non-winding columns 24 can not only reduce the magnetic loss of the magnetic core 2, but also improve the integration degree of the inductor and reduce the volume of the inductor. The number of the winding columns 23 shown in Fig. 4 is for example only and should not be used as a limitation on the number of the winding columns

23 in the accompanying drawings.

[0026] In another example, the number of the winding columns 23 may be three or more.

[0027] In the present embodiment, the magnetoresistance of the non-winding columns 24 is less than that of the winding columns 23. That is, there is no air gap 10 in side columns in the present embodiment.

[0028] Above, in the present embodiment, on the one hand, winding on the winding columns 23 causes the current to generate the magnetic fluxes with opposite directions and the same size on the two winding columns 23, and since the same air gaps 10 are formed in the two winding columns 23, there is no air gap 10 in the non-winding columns 24, so that the magnetic fluxes of the two winding columns 23 cancel each other on the non-winding columns 24, thus, the cross-sectional area of the two non-winding columns 24 may be reduced, and then the volume of the magnetic core 2 may be reduced. The loss of the magnetic core 2 may be reduced compared with an inductor with a large cross-sectional area, and the circuit efficiency may be improved. Reducing the cross-sectional area of the non-winding columns 24 will not block the heat dissipation of the winding columns 23.

[0029] On the other hand, according to the actual heat dissipation situation or the symmetry situation of circuit parameters, differentiated adjustment of the number of turns and differentiated adjustment of the side columns may also be carried out, respective corresponding optimization is performed considering that actual heat dissipation situations of two integrated inductors are different, so that the coils 1 and magnetic core 2 of a magnetic element may be used to the maximum degree.

[0030] It is worth mentioning that in order to highlight the innovative part of the present application, units less closely related to solving the technical problems raised in the present application are not introduced in the present embodiment, but this does not mean that other units do not exist in the present embodiment.

Claims

1. An inductor, wherein the inductor comprises a plurality of coils and a magnetic core;

   the magnetic core comprises: an upper bottom plate and a lower bottom plate, which are arranged in parallel up and down, a plurality of winding columns, which are located between the upper bottom plate and the lower bottom plate, and around which the plurality of coils are wound, and at least one non-winding column, which is arranged between the upper bottom plate and the lower bottom plate; and
   the numbers of turns of coils on at least two of the winding columns are different, directions of currents in the coils are opposite, there are air gaps in the at least two winding columns, around which the coils are wound for different numbers of turns, and the sizes of the air gaps in the winding columns are different.

2. The inductor of claim 1, wherein the numbers of turns of coils on two winding columns are different, and the two winding columns are a first winding column and a second winding column; and
   the number of turns of the coil wound around the first winding column is greater than the number of turns of the coil wound around the second winding column, and the air gap in the second winding column is smaller than the air gap in the first winding column.

3. The inductor of claim 2, wherein the first winding column and the coil form a first inductance, and the second winding column and the coil form a second inductance; and
   an inductance value of the first inductance is the same as that of the second inductance.

4. The inductor of claim 1, wherein the air gaps are located in positions of the winding columns away from the upper bottom plate and the lower bottom plate, and each winding column is connected with the upper bottom plate and the lower bottom plate.

5. The inductor of claim 1 or 4, wherein the air gaps are single-segment air gaps or multi-segment air gaps.

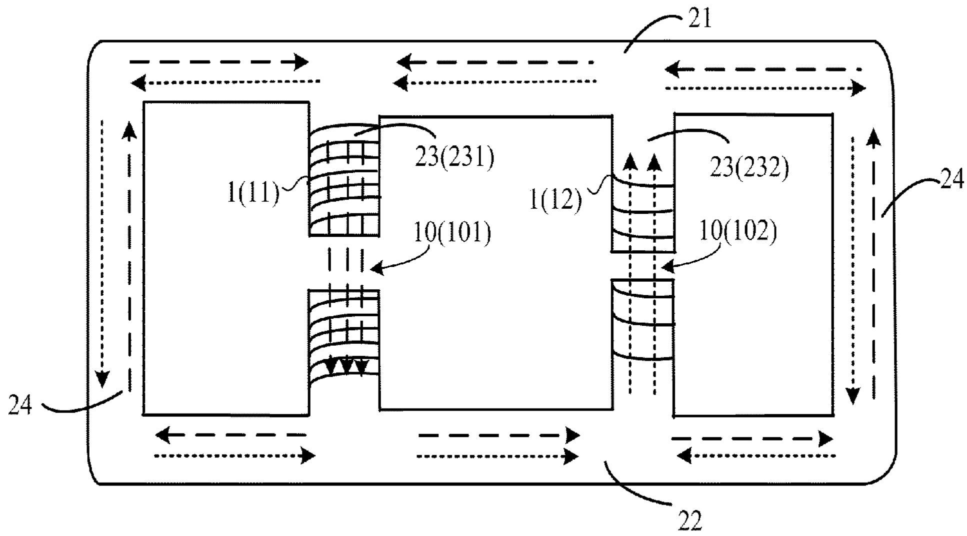
6. The inductor of claim 1 or 2, wherein the number of the non-winding columns is two, and the plurality of winding columns are located between the two non-winding columns; and
   the coils on the plurality of winding columns are set in a way that magnetic fluxes formed by the two non-winding columns cancel each other.

7. The inductor of claim 6, wherein the number of the winding columns is two, and the two winding columns and the two non-winding columns are arranged in a row.

8. The inductor of claim 1, wherein the non-winding column, the winding columns, the upper bottom plate and the lower bottom plate are integrally formed.

9. The inductor of claim 1, wherein a material of the magnetic core comprises ferrite, an amorphous body, a magnetic powder core or silicon steel.

10. The inductor of claim 1, wherein magnetoresistance of the non-winding column is less than that of the winding columns.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23(231)
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1(12)
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10(101)
10(102)
24
22

Fig. 1

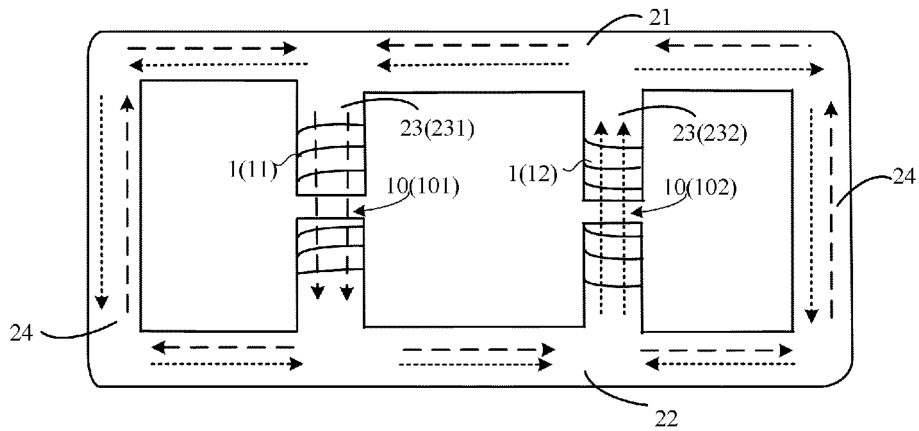
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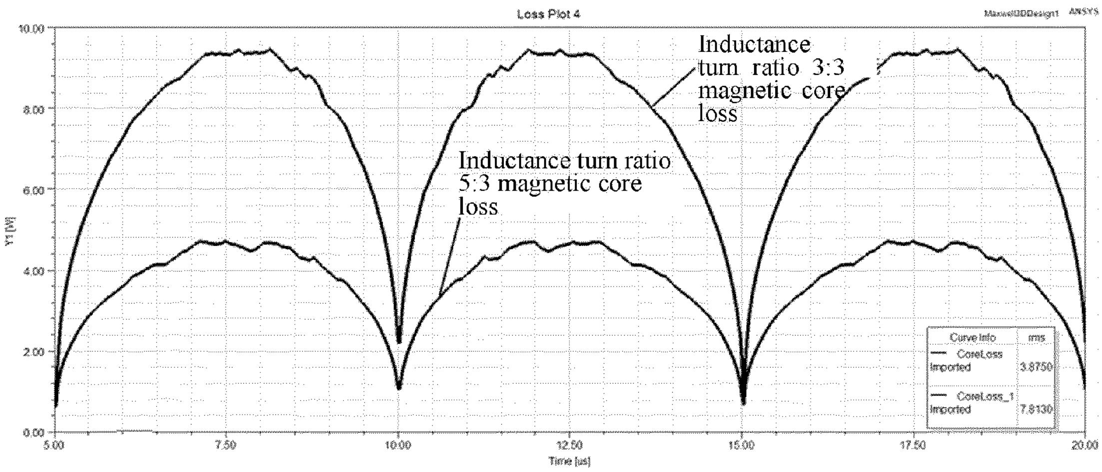
Fig. 2


Loss Plot 4
Maxwell3DDesign1 ANSYS
Inductance turn ratio 3:3 magnetic core loss
Inductance turn ratio 5:3 magnetic core loss
Y1 [W]
Time [us]
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2.00
4.00
6.00
8.00
10.00
5.00
7.50
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17.50
20.00
Curve Info rms
CoreLoss Imported 3.8750
CoreLoss_1 Imported 7.8130

Fig. 3

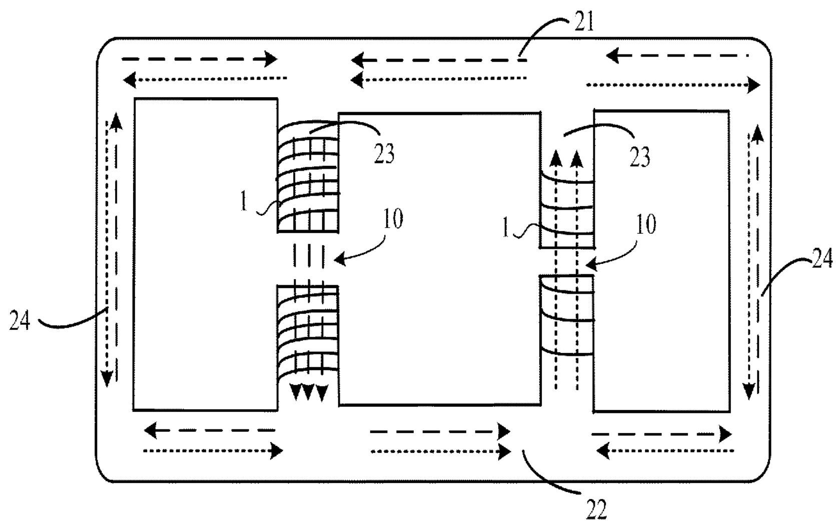
21
23
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Fig. 4

INTERNATIONAL SEARCH REPORT	International application No. PCT/CN2022/098775

A. CLASSIFICATION OF SUBJECT MATTER

H01F 27/30(2006.01)i; H01F 27/28(2006.01)i

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)

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)

VEN; DWPI; CNABS; CNTXT; ENTXT; WOTXT; EPTXT; 读秀, DUXIU; CNKI: 电感, 线圈, 匝数, 气隙, 铜损, 磁损, 芯, inductor, coil, number of turns, air gap, copper loss, magnetic loss, core

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	CN 102360863 A (TAMURA CHINA ENTPR MAN CO., LTD. et al.) 22 February 2012 (2012-02-22) description, paragraphs 22-35, and figures 1-6	1-10
Y	北京邮电学院一系 网络理论教研室 (Non-official translation: "Network Theory Teaching and Research Section", Department I of Beijing University of Posts and Telecommunications). ""3.5 磁芯的空气隙" (Non-official translation: "3.5 Core Air Gap")" *电信网络制作及元件 (Telecom Network Fabrication and Components),* 31 July 1979 (1979-07-31), pp. 43-44	1-10
Y	CN 107610880 A (ANHUI UNIVERSITY) 19 January 2018 (2018-01-19) description, paragraphs 20-34, and figures 1-5	1-10
Y	CN 208834872 U (ANHUI DYNAMIC POWER CO., LTD.) 07 May 2019 (2019-05-07) description, paragraphs 21-27, and figures 1-6	1-2, 4-10

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

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
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- "P" document published prior to the international filing date but later than the priority date claimed
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 August 2022	**29 August 2022**
Name and mailing address of the ISA/CN **China National Intellectual Property Administration (ISA/CN)** **No. 6, Xitucheng Road, Jimenqiao, Haidian District, Beijing 100088, China**	Authorized officer
Facsimile No. **(86-10)62019451**	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2022/098775

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	JP 10135054 A (MATSUSHITA ELECTRIC IND. CO., LTD.) 22 May 1998 (1998-05-22) entire document	1-10

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2022/098775

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