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(54) **INTEGRATED INDUCTOR AND A METHOD FOR REDUCTION OF LOSSES IN AN INTEGRATED INDUCTOR**

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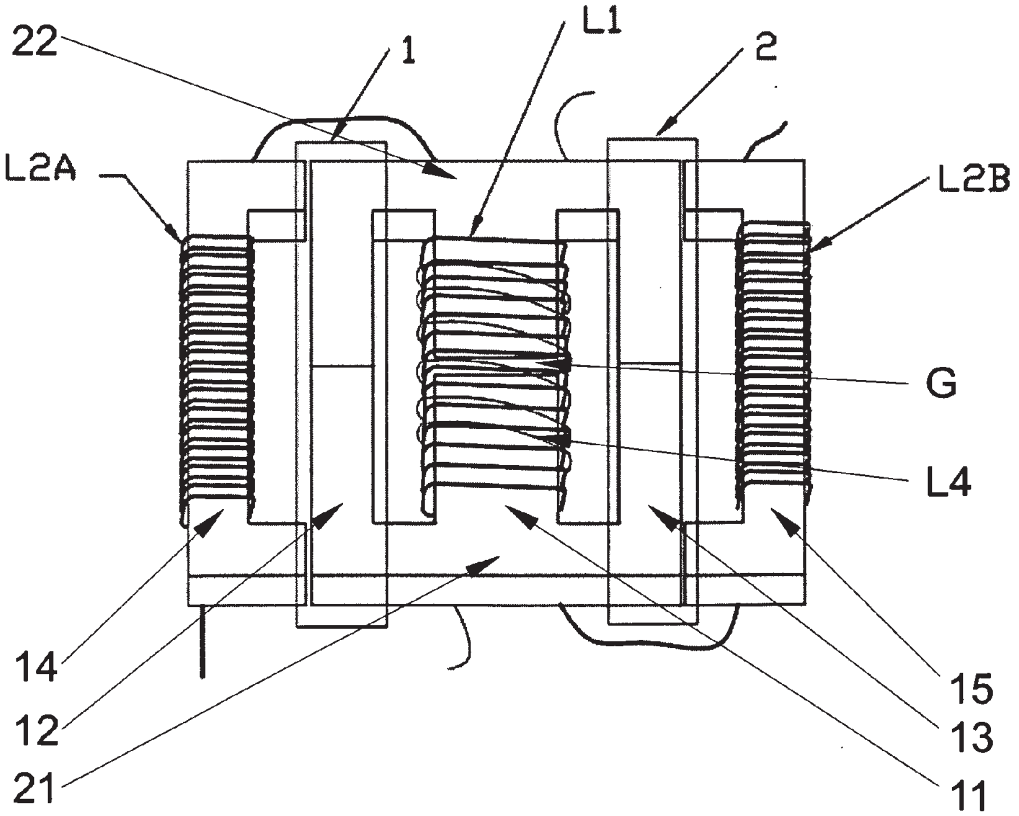
(57) **ABSTRACT**

An integrated inductor comprising a multi-winding inductor having a transformer winding (L**1**) and a resonant inductor (L**2**). Sections (**1**), (**2**) of the magnetic circuit of the transformer winding (L**1**) are incorporated into magnetic circuits of at least two parts (L**2**A), (L**2**B) of a resonant inductor (L**2**) so as to form common parts of magnetic circuit of the multi-winding inductor (L**1**) and at least two-part (L**2**A), (L**2**B) resonant inductor (L**2**), wherein the transformer winding (L**1**) of the multi-winding inductor is wound around a column (II), which has at least one air gap (G) having a width adapted so that the magnetic induction produced by the at least two-part (L**2**A), (L**2**B) resonant inductor (L**2**) does not exceed 25% of the magnetic induction produced by the transformer winding (L**1**) of the multi winding inductor.



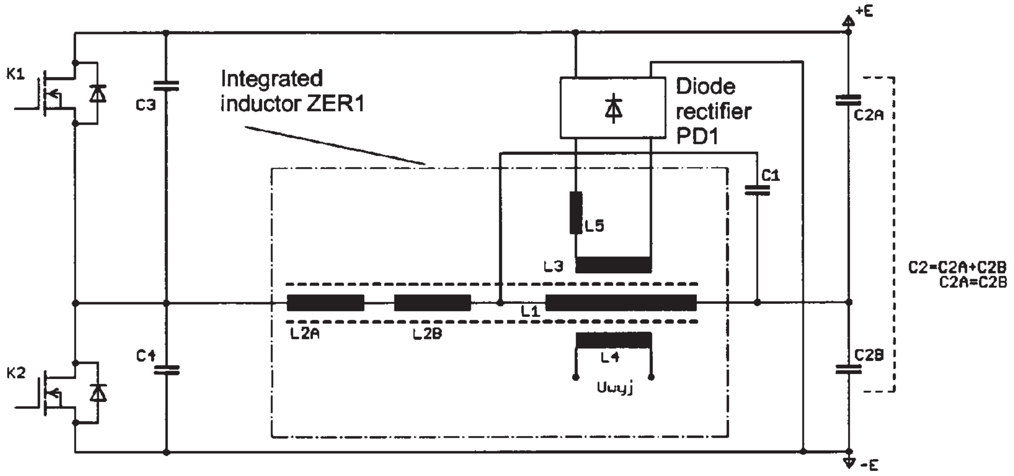

K1
C3
Integrated
inductor ZER1
Diode
rectifier
PD1
+E
C2A
C1
L5
L3
C2=C2A+C2B
C2A=C2B
L1
L2A
L2B
C4
K2
L4
Uwyj
C2B
-E

Fig. 1

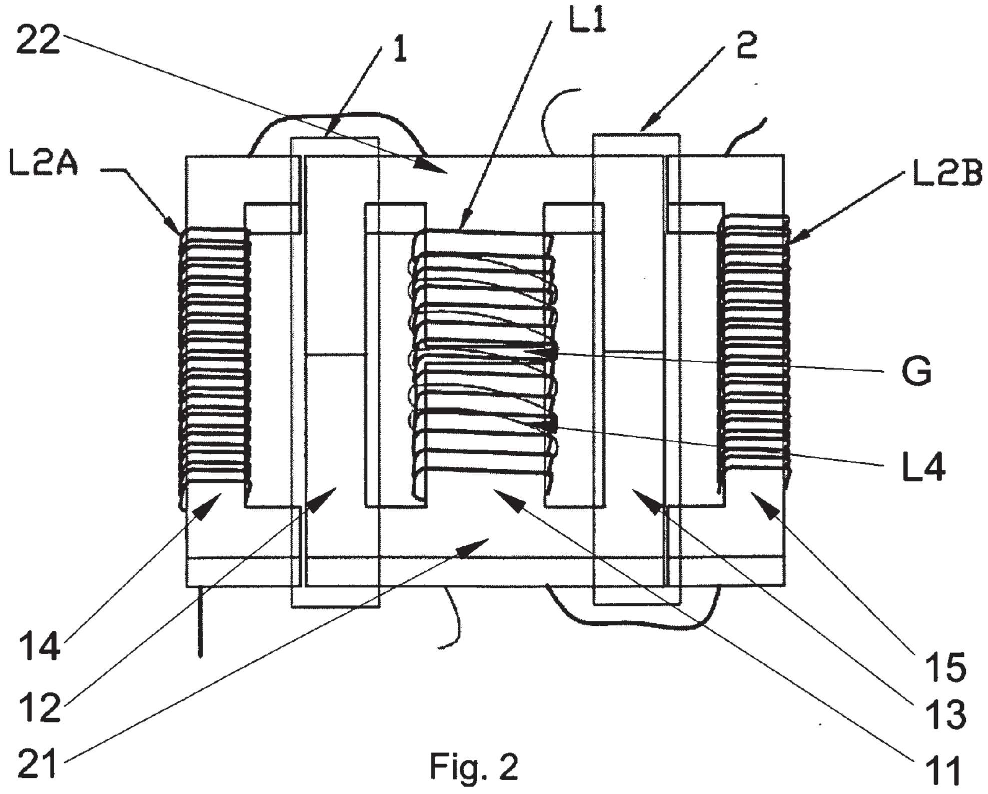

22
1
L1
2
L2A
L2B
G
L4
14
12
21
15
13
11

Fig. 2

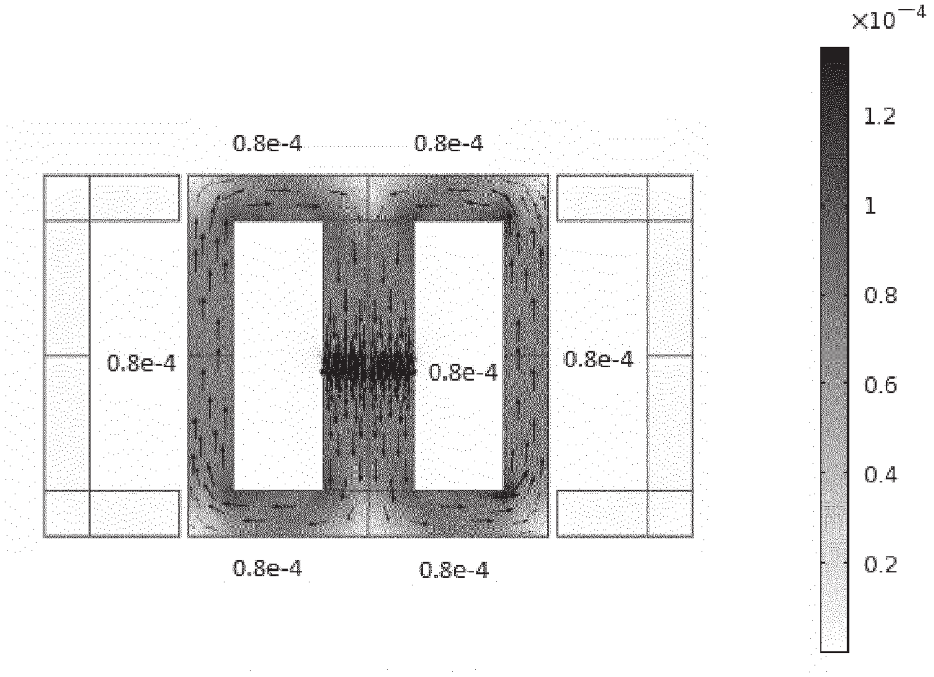

×10⁻⁴
1.2
1
0.8
0.6
0.4
0.2
0.8e-4
0.8e-4
0.8e-4
0.8e-4
0.8e-4
0.8e-4
0.8e-4
0.8e-4

Fig. 3

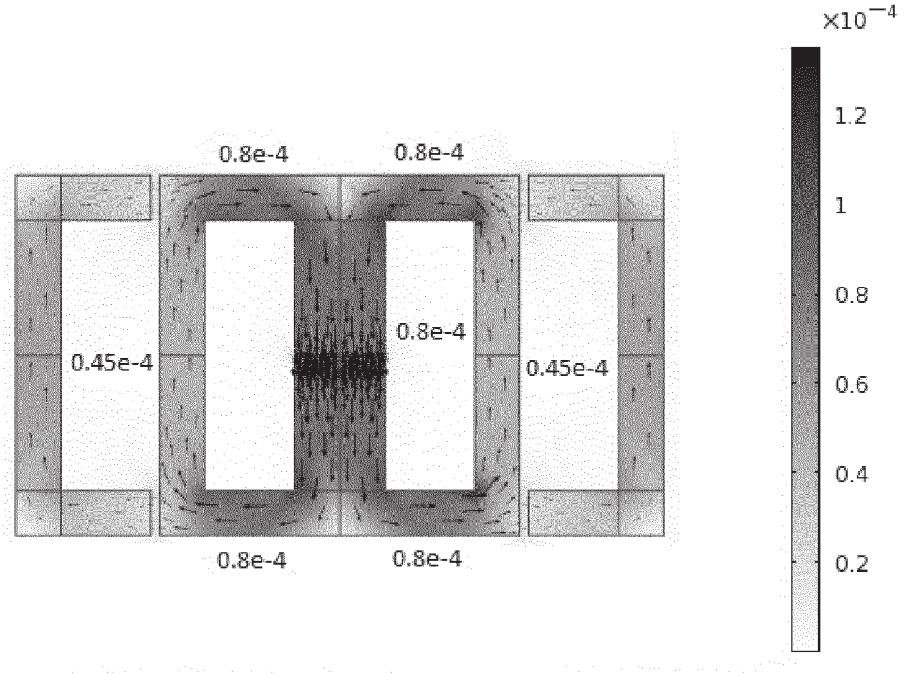

×10⁻⁴
1.2
1
0.8
0.6
0.4
0.2
0.8e-4
0.8e-4
0.8e-4
0.45e-4
0.45e-4
0.8e-4
0.8e-4

Fig. 4

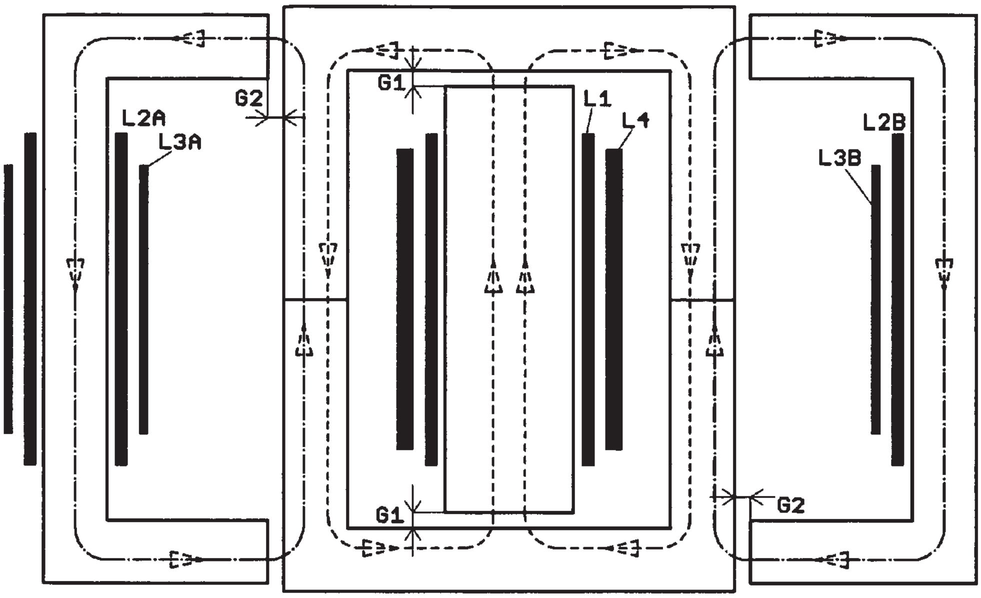

G2
G1
L1
L4
L2A
L3A
L2B
L3B
G1
G2

Fig. 5

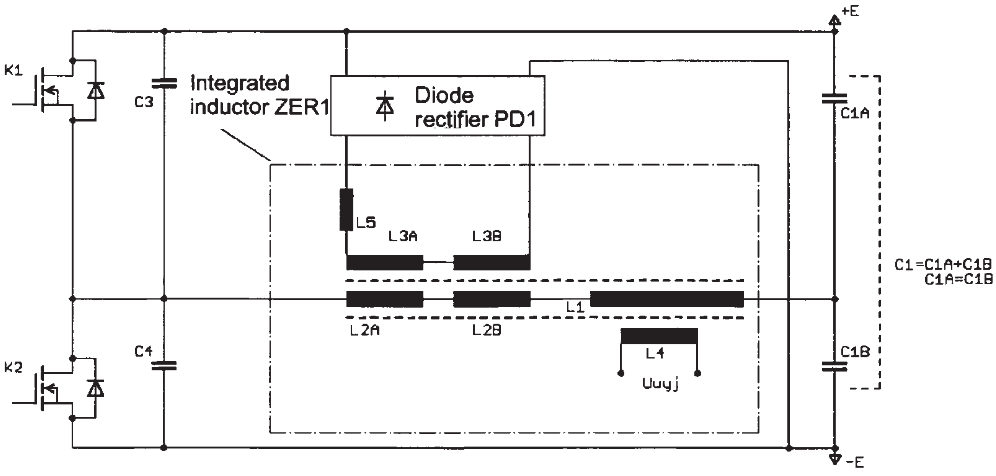

+E
K1
C3
Integrated
inductor ZER1
Diode
rectifier PD1
C1A
L5
L3A
L3B
C1=C1A+C1B
C1A=C1B
L1
L2A
L2B
L4
K2
C4
C1B
Uuyj
-E

Fig. 6

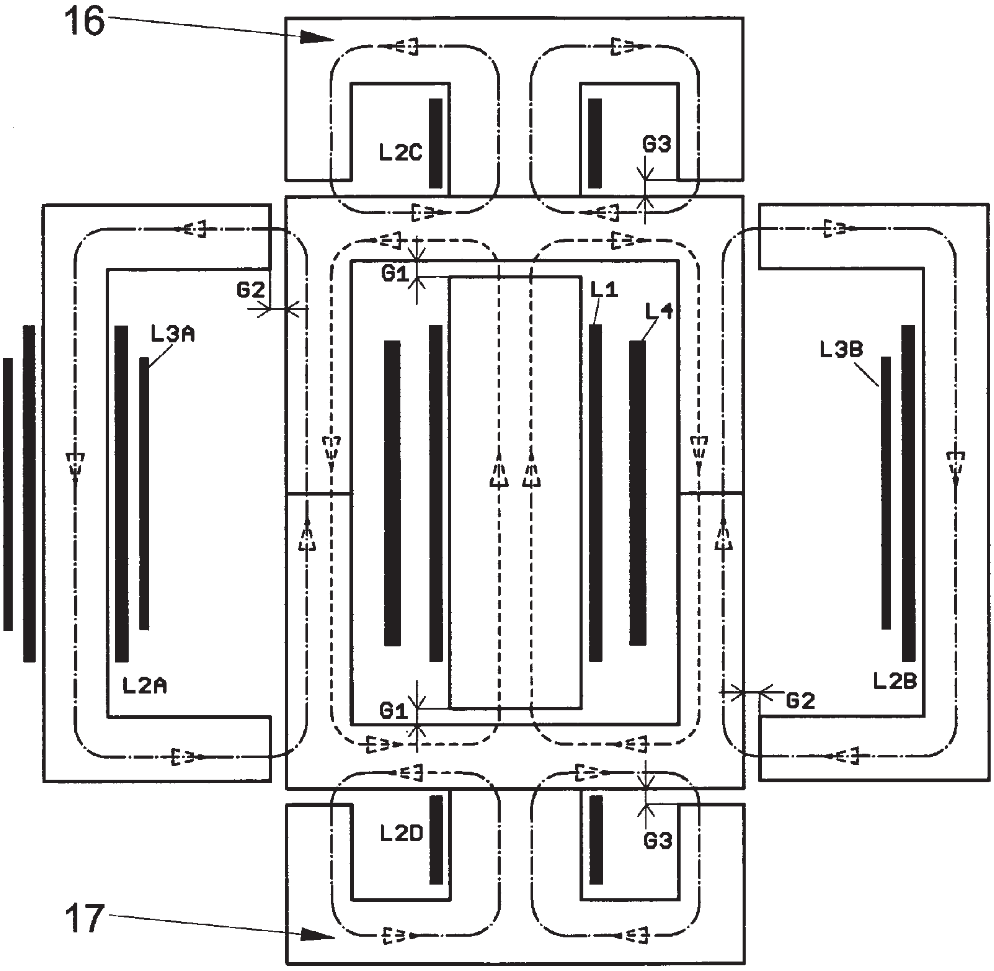

16
L2C
G3
G1
G2
L1
L4
L3A
L3B
L2A
L2B
G1
G2
L2D
G3
17

Fig. 7

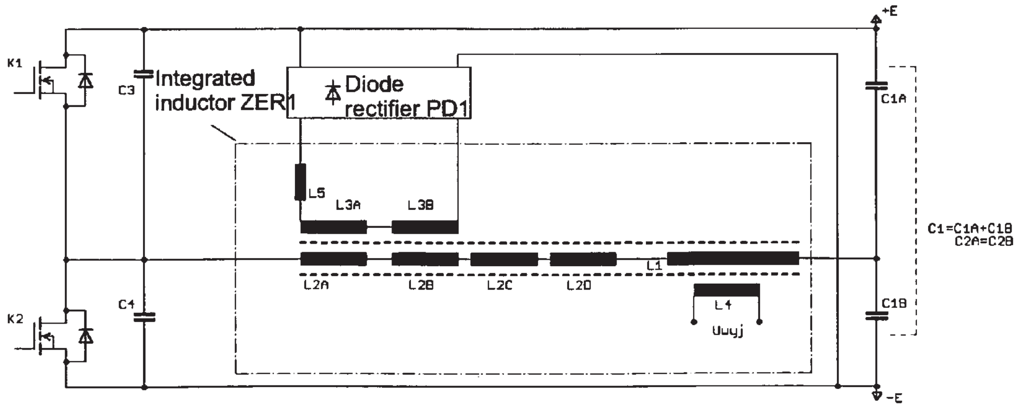

+E
K1
C3
Integrated inductor ZER1
Diode rectifier PD1
C1A
L5
L3A
L3B
C1=C1A+C1B
C2A=C2B
L1
L2A
L2B
L2C
L2D
L4
Uwyj
C4
C1B
K2
-E

Fig. 8

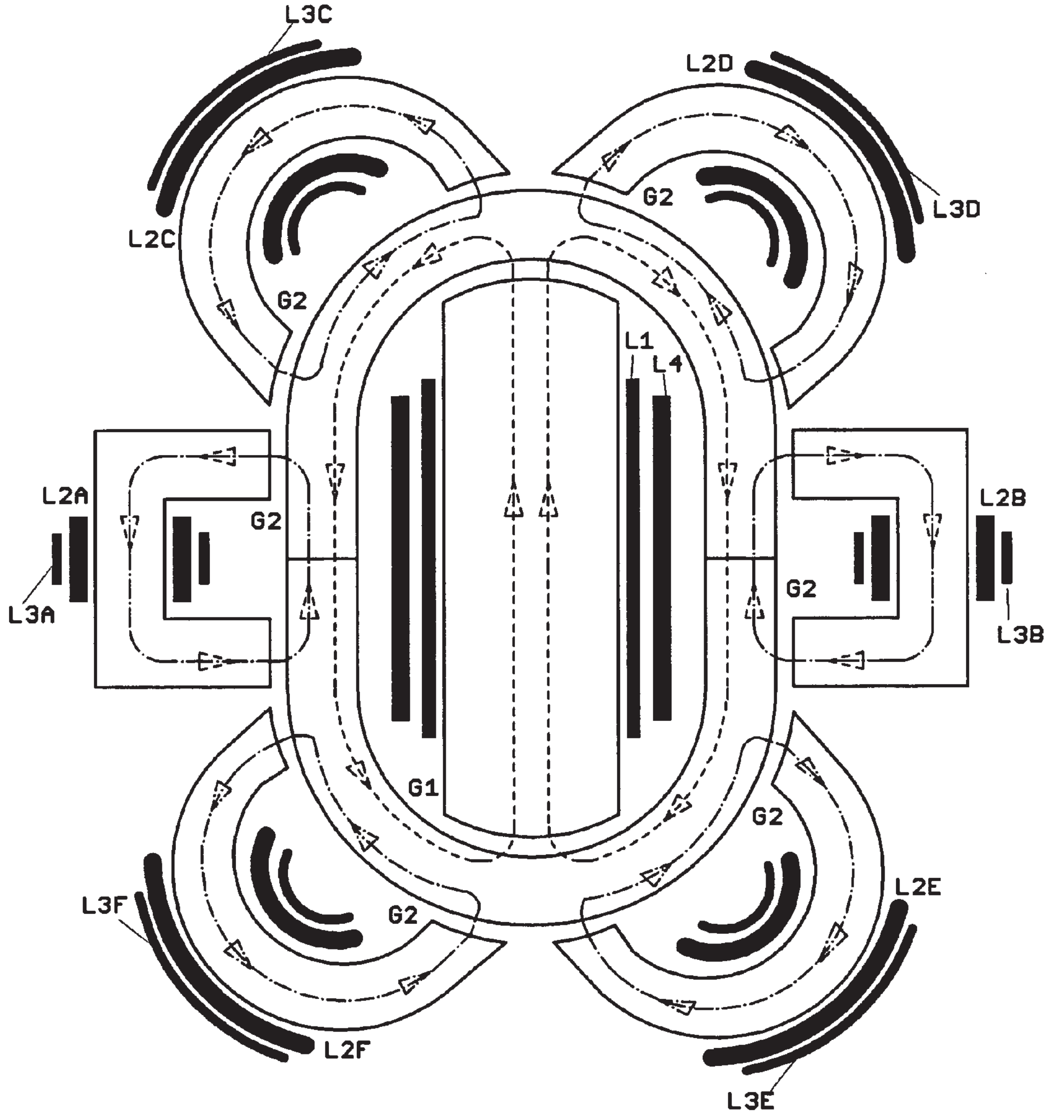

L3C
L2D
L2C
G2
L3D
G2
L1
L4
L2A
G2
L3A
L2B
G2
L3B
G1
G2
L3F
G2
L2E
L2F
L3E

Fig. 9

INTEGRATED INDUCTOR AND A METHOD FOR REDUCTION OF LOSSES IN AN INTEGRATED INDUCTOR

TECHNICAL FIELD

[0001] The present invention relates to an integrated inductor for use in resonant energy-conversion systems ensuring minimization of losses in a ferromagnetic core and to a method for reduction of losses in an integrated inductor.

BACKGROUND ART

[0002] Resonant energy-conversion systems, despite of their advantages, such as sinusoidal currents, soft switching capability, wide operating frequency range, etc., are relatively slowly superseding the classical solutions based on hard switching. The reason is that in a resonant circuit the peak current values are substantially exceeding the maximum load current. Therefore, the reactance elements, both the capacitors and inductors, shall be designed to store relatively large amounts of energy. This problem can be solved by increasing both the weight and dimensions of reactance elements. However, such approach is not economically viable, since it entails additional costs and, consequently, a higher price. A further unfavourable effect is the decrease in energy efficiency, because the increase in the inductive elements dimensions in resonant energy-conversion systems results in considerable losses in windings, particularly at frequencies above 100 kHz. Also increasing the ferromagnetic core dimensions, while maintaining a constant rms value of the magnetic flux density is the reason that losses increase linearly with the core volume. Recently, due to rising electricity prices and legislative measures aimed at limitation of electric power consumption and its rational utilization, the energy efficiency becomes the crucial parameter influencing the potential success of the proposed solution.

[0003] The U.S. Pat. No. 5,886,516 presents an integrated multi-winding magnetic element intended for operation in a series resonant converter, in which on a single "UU" gapped magnetic core there are located two windings of an isolation transformer and two additional windings constituting two inductive elements of the resonant circuit. This assembly constitutes a resonant circuit consisting of three inductances, two capacitances and the isolation transformer.

[0004] An integrated-magnetic apparatus is known from the U.S. Pat. No. 5,726,615 comprising three ferromagnetic pot cores, two of which have central core-columns carrying two flat windings placed around these columns. These two inductive elements constitute a transformer. The third ferromagnetic pot core has a shorter central core-column around which a flat winding is placed. The third core-piece located adjacent to a flat exterior surface of the transformer allows to form the third inductive element. The third inductive element is partially coupled magnetically through an air gap to the other windings and is phased to have the magnetic induction in the same direction as the magnetic induction in the ungapped magnetic circuit.

[0005] The U.S. Pat. No. 7,525,406 presents a structure that contains a plurality of coupled and non-coupled inductive elements and at least one closed magnetic circuit comprised of mutually contiguous magnetic elements having groves for current conductors in the X-axis and a perpendicular Y-axis. The current conductors located along the same axis exhibit mutual inductance but none between mutually orthogonal axes.

[0006] The Polish patent application No. 393133 presents a method for increasing the power transferred by an integrated inductor characterized by positioning an integrated inductor's windings orthogonally with respect to each other and the choice of induction elements values so that magnetic flux of the auxiliary magnetic circuit is transferred through at least a portion of the main magnetic circuit transferring the main magnetic flux while both magnetic induction vectors are oriented orthogonally with respect to each other, in addition both variable in time magnetic induction vectors are shifted with respect to each other in the time domain.

[0007] In the article "1MHz-1kW LLC Resonant Converter with Integrated Magnetics", Zhang, Yanjun Xu, Dehong Mino, Kazuaki Sasagawa, Kiyoaki, Applied Power Electronics Conference, APEC 2007—Twenty Second Annual IEEE, Feb. 25, 2007-Mar. 1, 2007, pp. 955-961, there is described an integrated magnetic module in which the region of magnetic induction compensation is restricted to a small portion of the magnetic core volume. Moreover, in this element there occurs a problem of large resonant induction values with respect to the transformer induction value and also a relatively large effect of increasing the resistance of copper windings being in magnetic field from air gaps in magnetic circuits.

[0008] The article "Planar Integrated Magnetics Design in Wide Input Range DC-DC Converter for Fuel Cell Application", Ziwei Ouyang, Zhe Zhang, Ole C. Thomsen, Michael A. E. Andersen, Ole Poulsen, Thomas Björklund, Energy Conversion Congress and Exposition (ECCE), 2010 IEEE: 12-16 Sep. 2010, pp. 4611-4618, also describes an integrated magnetic module in which the region of magnetic induction compensation is restricted to a small portion of the magnetic core volume. In this solution, a so-called hot spot occurs, where magnetic induction vectors produced by inductive elements of integrated magnetic circuits are summing up.

[0009] The above examples illustrate integrated reactances intended for use in resonant DC/DC converters. Nevertheless, said integrated reactances do not fully utilize the multi-winding inductor as an output transformer in resonant energy-conversion systems, and therefore, a reduction of thermal losses in inductive elements of the resonant circuit.

[0010] It would be, therefore, advisable to develop an integrated reactance element, characterized by reduced thermal losses in its resonant circuit inductive elements, and suitable for use in resonant DC/DC converters.

DISCLOSURE OF THE INVENTION

[0011] The object of the invention is an integrated inductor comprising a multi-winding inductor having a transformer winding and a resonant inductor, wherein sections, of the magnetic circuit of the transformer winding are incorporated into magnetic circuits of at least two parts, of a resonant inductor so as to form common parts of magnetic circuit of the multi-winding inductor and at least two-part, resonant inductor, wherein the transformer winding of the multi-winding inductor is wound around a column, which has at least one air gap having a width adapted so that the magnetic induction produced by the at least two-part, resonant inductor does not exceed 25% of the magnetic induction produced by the transformer winding of the multi-winding inductor.

[0012] Preferably, the transformer winding of the multi-winding inductor is wound around the column in a single layer.

[0013] Preferably, the transformer winding of the multi-winding inductor is a pitched winding wound around the column.

[0014] Preferably, in that the column, over which the transformer winding of the multi-winding inductor is wound, comprises two air gaps at its ends.

[0015] Preferably, the integrated inductor it comprises magnetic core-pieces that constitute a magnetic circuit with parallel columns magnetically connected with the yoke whereas the transformer winding of the multi-winding inductor is wound on the column parallel to columns on which the windings, of the resonant inductor are wound.

[0016] Preferably, the integrated inductor further comprises columns, parallel to the yoke, with further windings of the resonant inductor which are wound around said columns.

[0017] Preferably, the integrated inductor comprises magnetic core-pieces circumferentially arranged around the column having the transformer winding, wherein windings of the resonant inductor are wound on said magnetic core-pieces.

[0018] Another object of the invention is a resonant power supply comprising the integrated inductor according to the invention, wherein the multi-winding inductor acts as the output transformer and the inductive element is connected in series through the resonant inductor with transistor switches.

[0019] The invention also relates to a method for reduction of losses in an integrated inductor comprising a multi-winding inductor having a transformer winding and a resonant inductor, wherein sections, of the magnetic circuit of the transformer winding are incorporated into magnetic circuits of at least two parts, of the resonant inductor so as to form common parts of magnetic circuit of the multi-winding inductor and at least two-part resonant inductor wherein the transformer winding of the multi-winding inductor is wound around a column, which has at least one air gap having a width which is adapted so that the magnetic induction produced by the at least two-part, resonant inductor does not exceed 25% of the magnetic induction produced by the transformer winding of the multi-winding inductor.

BRIEF DESCRIPTION OF DRAWINGS

[0020] The invention is shown by means of exemplary embodiments on a drawing, in which:

[0021] FIG. **1** shows a half-bridge structure of a multi-resonance power supply with a quality-factor limiter based on an integrated inductor ZER according to the first embodiment.

[0022] FIG. **2** shows the first embodiment of the integrated inductor wherein variable magnetic inductions produced by the multi-winding inductor, which also functions as an output transformer, and by the resonant inductor, are oriented parallel with respect to each other in such a manner that the resultant time-variable vector of both magnetic inductions attains its minimum value.

[0023] FIG. **3** shows exemplary simulation of magnetic induction distribution in the integrated inductor according to the first embodiment wherein the current flowing in the resonant inductor L**2**=L**2**A+L**2**B equals 0 arbitrary units, whereas the current flowing in the L**1** coil equals 0.67 arbitrary units. The central column of the magnetic core incorporates an air gap.

[0024] FIG. **4** shows exemplary simulation of magnetic induction distribution in the integrated inductor according to the first embodiment, wherein the current in the resonant inductor L**2**=L**2**A+L**2**B equals 1 arbitrary unit, whereas the current in the L**1** coil equals 0.67 arbitrary units. The magnetic core central column incorporates an air gap and the directions of currents are chosen so that they are opposite in phase (a 180° phase shift).

[0025] FIG. **5** shows schematically the second embodiment of the integrated inductor, and FIG. **6** shows the example of its application in a resonant power supply circuit.

[0026] FIG. **7** shows schematically the third embodiment of the integrated inductor, and FIG. **8** shows the example of its application in a resonant power supply circuit.

[0027] FIG. **9** shows schematically the fourth embodiment of the integrated inductor's spatial structure.

MODES FOR CARRYING OUT THE INVENTION

[0028] FIG. **1** shows the first example of application of the integrated inductor according to the invention in a resonant-mode power supply circuit. The integrated inductor ZER**1** comprises a resonant inductor L**2** consisting of two inductive elements L**2**A and L**2**B connected in series and a multi-winding inductor, which also acts as the output transformer, composed of three inductive elements L**1**, L**3**, L**4** having a common magnetic circuit. The inductive element L**1** is connected in series through the inductor L**2**=L**2**A+L**2**B with transistor switches K**1**, K**2**; the output winding L**4** and the quality-factor limiter winding L**3** and the inductor L**5** are connected to the diode voltage limiter PD**1**. The primary winding is also connected with the capacitive circuit C**2**=C**2**A+C**2**B. Due to a series connection of the capacitive circuit C**2**=C**2**A+C**2**B with the inductor L**2**=L**2**A+L**2**B, the resulting impedance of these elements is strongly dependent on frequency, which allows controlling the voltage provided to the secondary winding L**4** of the multi-winding inductor. Because at resonance, the value of the voltage at the winding of the multi-winding inductor may achieve high values, a circuit for limiting good has been employed, which forms a control winding L**3** connected with the inductor L**5** and a diode viotabe limiter PD**1**.

[0029] FIG. **2** shows the first embodiment of the integrated inductor according to the invention. The integrated inductor comprises two “E” shaped core-pieces assembled with their legs joined together and two “U” shaped core-pieces whose legs are joined to the corners of said two “E” shaped core-pieces. These core-pieces constitute columns **11**, **12**, **13**, **14**, **15** parallel with respect to each other whereas the multi-winding inductor winding L**1** is wound around the column **11**. The intermediate columns **12**, **13** have no windings. Around outer columns **14**, **15** there are wound windings L**2**A, L**2**B of the two-part resonant inductor L**2**. Columns **11**-**15** are connected by means of yokes **21**, **22** that close the magnetic circuit. Such configuration ensures minimum leakage flux from the multi-winding inductor whereof the main flux closes within the “E” core-pieces. Furthermore, the multi-winding inductor magnetic circuit comprises at least one air gap G that enables controlling the maximum magnetic induction value in the magnetic core and therefore power losses occurring in the core. The width of the air gap G is chosen so that magnetic induction produced by the at least two-part L**2**A, L**2**B resonant inductor L**2** does not exceed **25**% of the magnetic induction produced by the multi-winding inductor's transformer winding L**1**. Moreover, such construction with a single-layer, preferably pitched, winding having a break over the air gap minimizes the magnetic coupling between magnetic elements, ensures symmetry of the windings and minimizes the losses associated with the influence of magnetic field around the air gap. The resonant inductor winding utilizes two "U" shaped core-pieces on which the windings L**2**A and L**2**B are placed. In the embodiment shown in FIG. **3** and FIG. **4** the preferable directions of magnetic induction produced by the integrated inductor windings are depicted in the form of curves drawn in dashed lines with arrowheads indicating the direction, while in FIG. **3** the current flows only through the element L**1**, whereas in FIG. **4** through elements L**1** and L**2**. An advantageous feature of the integrated inductor shown in FIG. **2** is the ease of adjustment to different values of power transferred by means of typical magnetic elements of a suitable size. Due to parallel positioning of the multi-winding inductor winding L**1** with respect to resonant inductors' windings L**2**A and L**2**B, the magnetic inductions produced by these windings are also parallel oriented. The winding L**3**, most often wound over the L**1** winding, is not shown in FIG. **2** to increase its clarity. Furthermore, depending on the phase shift between both magnetic induction vectors achieved by means of an appropriate choice of relative values of the reactance elements incorporated in the resonant-mode power supply or by choice of an appropriate topology, the amplitude of magnetic induction can be reduced within a certain range and, consequently, a reduction of losses in the magnetic core can be achieved. For this purpose, the phase shifts between the magnetic inductions superimposing in a selected portion of the magnetic circuit are chosen so as to achieve the smallest possible losses. Preferably, the phase shift between magnetic induction vectors produced by inductors L**1** and L**2** is basically 180°.

[0030] It is well known to describe the losses in a ferromagnetic core by the equation:

$$P_V=P_{V,histerezy}+P_{V,prara\text{-}wirowe}+P_{V,resztkowe}$$

[0031] The losses $P_V(B,f,T)$ in a ferromagnetic core depend primarily on the magnetic induction B, the magnetic field frequency f and the core temperature T, whereas:

$$P_V(B)\approx B^{2+y}\text{where } y\in[0,1]$$

$$P_V(f)\approx f^{1+x}\text{where } x\in[0,1]$$

$P_V(T)$ attains its minimum near 90° C.

[0032] In the resonant-mode power supply according to FIG. **1** it is possible to achieve a constant phase shift of ca. +/−90° between the current in the inductor L**2**A and L**2**B and the current in the multi-winding inductor winding L**1**. Assuming equal amplitudes of the magnetic induction vectors, the resultant magnetic induction amplitude in the magnetic circuit portion where both magnetic fluxes are superimposing is:

$$B_{12}(t)=B_A\cdot(\sin\omega t+\cos\omega t)=B_A\cdot\sqrt{2}\cdot\sin(45°+\omega t)=B_{A12}\cdot\sin(45°+\omega t)$$

$$B_{A12}=B_A\cdot\sqrt{2}$$

[0033] Assuming both induction vectors are on the same plane but opposite in phase (a 180° phase shift) and assuming for sinusoidal waveforms the same amplitude of the inductions associated with coils (L**1**) and (L**2**=L**2**A+L**2**B) $B_{A1}=B_{A2}=B_A$, and if magnetic fields are shaped so that they cancel out, the resultant magnetic induction $B_{12}(t)$ in certain regions is B_{A12}:

$$B_{12}(t)=B_A\cdot(\sin\omega t-\sin(\omega t))=B_{A12}\cdot 0=0$$

[0034] The integrated inductor according to the invention has a particularly desirable feature that two inductive elements L**2**A, L**2**B utilize portions **1** and **2** of the multi-winding inductor and losses in common branches of magnetic circuits can be substantially reduced by means of reduction of the magnetic induction vector amplitude.

[0035] FIG. **3** and FIG. **4** show results of simulation of the magnetic induction vector distribution in the integrated inductor according to the invention. FIG. **3** illustrates the integrated inductor condition when the resonant inductor L**2**=L**2**A+L**2**B current equals 0 arbitrary units and the coil L**1** current is 0.67 arbitrary units. The central column of the magnetic core incorporates an air gap. This is the initial condition, which is the basis for comparison because there are no compensating magnetic inductions from the resonant inductor.

[0036] FIG. **4** shows simulation of the magnetic induction vector distribution in the integrated inductor in which the resonant inductor L**2**=L**2**A+L**2**B current equals 1 arbitrary unit and the current in coil L**1** is 0.67 arbitrary units. The central column of the magnetic core incorporates an air gap and directions of currents in windings L**1** and L**2** are chosen so that they are phase-shifted by 180°. In the external branches of the ferromagnetic core, the magnetic induction current has been decreased from a value of 0.8 arbitrary units to the value of 0.45 arbitrary units. In such a situation, it is possible to assess a relative change of the power of losses, assuming that there is a square relationship between the value of power of losses in the core and the value of the magnetic induction:

$$P_V(B)\approx B^2$$

[0037] If, for example, the magnetic induction amplitude is reduced within 33% of the core volume and the magnetic induction amplitude decreases from 0.8 arbitrary units to 0.45 arbitrary units then, due to the reduction of magnetic induction within 33% of the core volume, thermal losses in chosen portions of the magnetic circuit decrease by 67% and by 20% in the whole core.

[0038] FIG. **5** shows schematically the second embodiment of the integrated inductor, and FIG. **6** shows the example of its application in the resonant power supply circuit. The second embodiment is equivalent to the first one except for the fact that it contains two air gaps G**1** located at the ends of the column **11**, between the magnetic element of column **11** and the yoke **21**, **22**. The advantage of this solution over the configuration comprising a single gap G in the middle of the column **11** is that it allows to achieve the self-screening effect of magnetic field from air gaps (reduction in electromagnetic emission, minimization of losses associated with magnetic field near the air gap and minimization of couplings between magnetic elements through the external yoke) and allows to maintain a symmetry of magnetic fields distribution (equal number of volts-per-turn, independently on the position on the column). The second embodiment, similarly as the first one, comprises air gaps G**2** in the yoke connecting the column **11**, around which the transformer windings are wound, with the columns **14** and **15** with the resonant inductor windings L**2**A, L**2**B. The direction of magnetic induction produced by the transformer winding L**1** is shown with a dashed line and the direction of magnetic induction produced by he resonant inductor windings L**2**A, L**2**B is represented by a dashed-and-dotted line. In the second embodiment the height of the column **11** is larger than the distance between the column **11** and columns **14**, **15**, and therefore the transformer winding L**1** can be wound as a single-layer winding or, in the case of a larger length of the column **11**, as a pitched winding. A single-layer wound transformer winding L1 allows to reduce windings losses (reduction of the proximity effect) and also to attain as large as possible relative length of the common magnetic path (losses reduction in magnetic material) and enables a flat, planar construction. Reduction in parasitic capacitances of the transformer windings enables to increase the operating frequency.

[0039] FIG. **7** shows schematically the third embodiment of the integrated inductor, and FIG. **8** shows the example of its application in the resonant power supply circuit. The integrated inductor according to the third embodiment differs from the integrated inductor according to the second embodiment in that it has a four-element resonant inductor which, apart of windings L**2**A, L**2**B wound around columns **14**, **15** parallel to the column **11**, has also windings L**2**C, L**2**D wound around columns **16**, **17** parallel to the yoke **12**, **13**. That allows to additionally increase the volume of the magnetic material in which the reduction of magnetic induction occurs and, consequently, reduction of losses in the magnetic core.

[0040] Since under resonance conditions the voltage across the multi-winding inductor may attain large values, the solution incorporates a quality-factor limiting circuit that consists of the control winding L**3** connected with inductor L**5** and a diode voltage limiter PD**1**.

[0041] FIG. **9** shows schematically the fourth embodiment of the integrated inductor's spatial structure wherein the six-part resonant inductor's windings L**2**A, L**2**B, L**2**C, L**2**D, L**2**E, L**2**F are wound around columns **31**, **32**, **33**, **34**, **35**, **36**, arranged circumferentially around the column **11** carrying the transformer winding. The columns **31**-**36** can be curvilinear and in this embodiment they have the form of a half of a torus and thus facilitate the construction of a bobbin (also in the toroidal form) and winding of coils, and enable achieving significant reduction in core losses. The circumferential arrangement of columns **31**-**36** allows minimization of air gaps and thus effective reduction of magnetic flux leakage from the integrated magnetic element as well as compact, low profile construction and, consequently, substantial reduction of parasitic inter-turn capacitances.

1. An integrated inductor comprising a multi-winding inductor having a transformer winding (L**1**) and further comprising a resonant inductor winding (L**2**), both windings (L**1**, L**2**) wound around a magnetic core, characterized in that:

the resonant inductor winding (L**2**) comprises at least two resonant inductor winding parts (L**2**A, L**2**B),

and while currents flow simultaneously through the transformer winding (L**1**) and the resonant inductor winding (L**2**), the magnetic circuit of the transformer winding (L**1**) partially overlaps with the magnetic circuits of the resonant inductor winding parts (L**2**A, L**2**B) in the area of common parts (**1**), (**2**) of the core,

wherein the transformer winding (L**1**) of the multi-winding inductor is wound around a first column (**11**) of the core, wherein the part of core along the path of the magnetic flux flowing through the first column (**11**) and the common parts (**1**), (**2**) comprises at least one first air gap (G), (G**1**),

and wherein the resonant inductor winding parts (L**2**A), (L**2**B) are would around second columns (**14**), (**15**) of the core, wherein the part of core along the path of the magnetic fluxes flowing through the second columns (**14**), (**15**) and the common parts (**1**), (**2**) comprises second air gaps (G**2**),

and wherein the at least one first air gap (G, G**1**) has a width adapted so that the magnetic induction produced by the resonant inductor winding (L**2**) does not exceed 25% of the magnetic induction produced by the transformer winding (L**1**) in column (**11**) while currents flow simultaneously through both the transformer winding (L**1**) and the resonant inductor winding (L**2**).

2. The integrated inductor according to claim **1**, characterized in that the transformer winding (L**1**) of the multi-winding inductor is wound around the first column (**11**) in a single layer.

3. The integrated inductor according to claim **2**, characterized in that the transformer winding (L**1**) of the multi-winding inductor is a pitched winding wound around the first column (**11**).

4. The integrated inductor according to claim **1**, characterized in that the first column (**11**), comprises two air gaps (G**1**) at its ends.

5. The integrated inductor according to claim **1** characterized in that it comprises magnetic core-pieces that constitute the magnetic core with parallel columns (**11**-**15**) magnetically connected with the yoke (**21**, **22**) whereas the transformer winding (L**1**) of the multi-winding inductor is wound on the first column (**11**) parallel to the second columns (**14**, **15**).

6. The integrated inductor according to claim **5**, characterized in that it further comprises third columns (**16**, **17**), parallel to the yoke (**12**, **13**), with further windings (L**2**C, L**2**D) of the resonant inductor winding (L**2**) which are wound around said third columns (**16**, **17**).

7. The integrated inductor according to claim **1**, characterized in that it comprises magnetic core-pieces (**31**-**36**) circumferentially arranged around the first column (**11**) having the transformer winding (L**1**), wherein the resonant inductor windings (L**2**A, L**2**B, L**2**C, L**2**D, L**2**E, L**2**F) are wound on said magnetic core-pieces (**31**-**36**).

8. A resonant power supply comprising the integrated inductor according to claim **1**, wherein the multi-winding inductor acts as the output transformer and the transformer Winding (L**1**) is connected in series through the resonant inductor Winding (L**2**) with transistor switches (K**1**, K**2**).

9. (canceled)

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