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(54) **High leakage inductor for a switched power converter**

(57) Magnetic integration of a planar inductor (20) for a switched power converter including filtering means connected to a load to provide a zero-ripple current. The planar inductor (20) comprises a magnetic core having an E type standardised core section, on the external legs of which are wound, respectively, a first coil (21) and a second coil (22), being magnetically coupled to obtain a leakage inductance (21-2), such that the common magnetic flux observed respectively by both coils (21) and (22) is conducted through the ferromagnetic circuit formed by the external legs of the core, and the magnetic flux associated with the leakage inductance (21-2) is conducted through one external leg and the central leg.

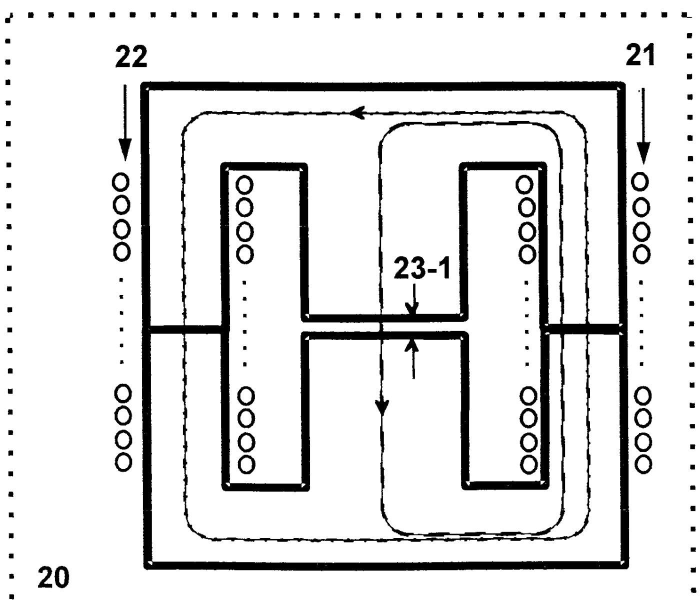

FIG. 2

EP 1 014 397 A1

Description

OBJECT OF THE INVENTION

[0001] The present invention relates to a magnetically integrated planar inductor to be employed in energy conversion processes in which use is made of input and/or output filtering means in a switched power supply converter. It is of special, but not exclusive application, in switched power converters for low power and low voltage applications, and, also, facilitates a high level of integration.

STATE OF THE ART

[0002] A compound inductor comprising two or more coupled windings for use in energy conversion processes in which switching takes place, is known from the United States patent US-A-5.481.238, being incorporated in the present patent application by reference.

[0003] An output filter that includes the compound inductor implemented according to the above mentioned United States patent, can be used in some converters, like a buck converter or a boost converter.

[0004] The compound inductor proposed in that patent comprises a first inductor having a first winding on a first magnetic core, a second inductor having a second magnetic core outside the winding coil of the first inductor, and a second winding around the first winding and the second core. One end of the first winding and the corresponding end of the second winding are electrically connected.

[0005] The main drawback of the inductor described in the United State patent mentioned is its high cost, due to the fact that it is complicated to manufacture because specific magnetic cores of different sizes and magnetic materials are used for obtaining appropriate electrical characteristics for the output filter of the switched power converter. Therefore the manufacturing process is not fully automated.

[0006] Consequently, it is necessary to develop filtering means comprising inductive means having a manufacturing process which is fully automated and in which standardised elements are employed.

[0007] As a consequence, the overall cost of the filtering means is reduced and, thereby, that of the switched power converter in which it is equipped.

CHARACTERISATION OF THE INVENTION

[0008] In order to overcome the problems described above, the magnetic integration of a planar inductor is proposed for use in some types of switched power converters having filtering means to smooth the current that is flowing through the power converter, and in which the planar inductor is the object of the present invention.

[0009] The design of the planar inductor of the invention alters the constructional process of said inductor in order that the current fed to the load satisfies the zero-ripple condition and, in addition, the manufacturing process employs standardised elements, for example planar magnetic cores having an E type section, and which do not require any special machining during said process.

[0010] As a result, the repeatability of the electrical characteristics of the planar inductor is ensured during the manufacturing process, and consequently they are not affected by the slight differences that could arise during said process. Consequently, the cost of the planar inductor of the output filter is considerably reduced and, also, the overall cost of the converter is diminished.

[0011] The switched power converter attains a high overall efficiency in the process of converting a voltage received from a voltage source to an output voltage and, in addition, it responds rapidly to variations in the load, finding particular use in those applications requiring low power and low voltage with a low profile and reduced size.

[0012] The planar inductor comprises a magnetic core having an E type standardised core section, on the outside legs of which are wound, respectively, a first coil and a second coil that are magnetically coupled to each other for producing a significant leakage inductance, such that one end of the first coil and the corresponding end of the second coil are electrically connected in a second node. The result being that the common magnetic flux observed respectively by both coils, is conducted through the ferromagnetic circuit formed by the outside legs of the magnetic core, and the magnetic flux associated with the leakage inductance is conducted by one outside leg and the centre leg.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A more detailed explanation of the invention is provided in the following description, based on the figures attached, in which:

- figure 1 shows an electrical schematic of a buck converter according to the invention,
- figure 2 shows, in an elevation view of the inductor core used in the construction of the buck converter, the distribution of the magnetic flux according to the invention,
- figure 3 shows a preferred embodiment of the inductor core used in the construction of the buck converter according to the invention, and
- figure 4 shows another electrical schematic of a boost converter according to the invention.

DESCRIPTION OF THE INVENTION

[0014] Figure 1 shows a single output buck converter that incorporates filtering means 14 connected directly to a load, said means being designed to smooth an output current so that its ripple is zero, the zero ripple condition.

[0015] The buck converter is used merely as an example in order to achieve a better description of the present invention, it being possible to use other types of switched converters, all having an output or an input filter, achieving similar results.

[0016] The buck converter is connected via input terminals 11 and 12 to a voltage source, representing one of the input terminals 12 a common voltage reference of said converter.

[0017] One of the input terminals 11 is connected to a first terminal 13-1 of a first switching means 13, for example a field effect transistor, type MOSFET. A second terminal 13-2 is connected to an input terminal 14-1 of the filtering means 14. The first switching means includes a third terminal (not shown) over which a signal is received to adapt the ON and OFF periods of the first switching means 13 in order to produce a regulated output voltage across output terminals 14-3 and 14-4.

[0018] A first node 16, situated on the conducting line that connects the second terminal 13-2 with the input terminal 14-1, is connected to a first terminal 15-1 of a second switching means 15, and a second terminal 15-2 of the second switching means 15 is connected to the common voltage reference of the converter, forming a rectifier branch. For example, the second switching means 15 can be a unidirectional conducting device such as a diode.

[0019] The terminal 14-2 of the filtering means 14 is also connected to the common voltage reference. The filtering means 14 receives energy from the voltage source during the ON periods of the first switching means 13, and produces across its output terminals 14-3 and 14-4 the smoothed output voltage and an output current with ripple close to zero, which are respectively applied to the load, this being possibly telecommunications equipment.

[0020] The filtering means 14 includes a planar inductor 20 comprising at least a first coil 21 located on the conducting line that connects terminal 14-1 with terminal 14-3, a series combination of a second coil 22 and a second storage capacitor 22-1 being connected to a second node 24 situated between the terminal 14-1 and an end of the first coil 21. Consequently the series combination is connected in parallel with the second switching means 15.

[0021] A first storage capacitor 21-1 is connected in parallel with the load in order to smooth the current which flows through the first coil 21, so that the means value of this current is zero.

[0022] The two coils 21 and 22 of the inductor 20 are wound around a magnetic core 23, being magnetically coupled to each other. The coupling coefficient between said coils 21 and 22 is less than unity due to the fact that they have a different number of turns.

[0023] The inductor 20 is constructed in such a manner that it introduces a significant leakage inductance between said coils 21 and 22. The leakage inductance is represented on figure 1 by means of a third coil 21-2, which is connected in series with an end of the first coil 21 and with an end of the first capacitor 21-1.

[0024] In order to comply with the zero ripple condition in the output current, the magnitude of the inductance of the third coil 21-2 has to reach a high value, due to the fact that the current ripple is a function of the ratio between the magnitude of the voltage drop across the third coil 21-2 and the value of its inductance; consequently the latter has to be as high as possible.

[0025] The voltage seen by the inductance 21-2 is the difference in voltage between the voltage on the second capacitor 22-1 and that on the first capacitor 21-1.

[0026] Figure 3 shows the preferred embodiment of the magnetic core 23 used in the construction of the inductor 20 in order to reach the results desired with the invention. The core 23 comprises at least two standardised core sections, and at least one of the sections is of an E type, i.e. a three-leg core.

[0027] Figure 2 shows each of the coils 21 and 22 respectively wound around an outside leg of the type E section, and where one end of the first coil 21 and the corresponding end of the second coil 22 are electrically connected at the second node 24.

[0028] In order to simplify the manufacturing process of the inductor 20, the turns of each of the coils 21 and 22 are laid on printed circuit board, being possibly of the multi-layer type. As a result, the manufacturing process of the planar inductor 20 of the invention is relatively insensitive to tolerances and guarantees a high degree of repeatability of said process.

[0029] The operation of the buck converter is explained as follows: during a period when the first switching means 13 is conducting, the same power as is applied across the input terminals 11 and 12 is applied to the input terminals 14-1 and 14-2 of the filtering means 14, which is greater than the voltage present across the output terminals 14-3 and 14-4.

[0030] As a result, there is a growing current flowing from the terminals 11 and 12 charging the capacitors 21-1 and 22-1. The inductor 20 starts to charge, storing a certain amount of energy as well as feeding current to the load. During this time interval, there is a direct transfer of power from the input to the output.

[0031] At the moment when the first switching means 13 is turned OFF, the incoming current to the filtering means 14 cannot be cut off abruptly, for which reason the second switching means 15 starts to conduct.

[0032] At this moment, the voltage applied to the input of the filtering means 14 is less than that applied to the terminals 14-3 and 14-4. Consequently, the current through the filtering means 14 has the same direction as before, but is decreasing. At the moment when the first switching means 13 resumes conduction, the second switching means 15 stops conducting and the cycle is re-initiated.

[0033] The main objective of the magnetic integration of the planar inductor 20 is to shunt the alternating current (AC) received by the filtering means 14 into the second coil 22; consequently, the first coil 21 only receives the direct current (DC), whereby the output voltage is smoothed more easily. As a result, the series combination of the second coil 22 and the second capacitor 22-1 receives only AC current with a mean value equal to zero. Consequently, the output current satisfies the zero ripple condition.

[0034] The electrical characteristics of the filtering means 14 are unchanged by the incorporation of the series combination mentioned. Thus, the inductor 20 is designed to confine the common magnetic flux observed respectively by the two coils 21 and 22, through the ferromagnetic circuit formed by the outside legs of the core 23. And the flux observed by the third coil 21-2 is conducted through the ferromagnetic circuit formed by the centre leg and the outside leg on which the first coil 21 is wound. The centre leg has a predetermined air gap 23-1, in order to limit the magnitude of this last flux.

[0035] Likewise, the outside legs have a second air gap, which is much less than the first air gap 23-1 of the centre leg, for limiting the magnitude of the common magnetic flux and prevent the core 23 from saturating.

[0036] Figure 4 shows the filtering means 14 of the invention in a switched power converter of the boost type. Its operation is not described here, as it is similar to that of the buck converter.

[0037] From the foregoing description, it can be deduced that the switched power converter comprising the filtering means 14 of the invention is preferentially implemented with planar integrated magnetic devices, the coils of which are laid on printed circuit boards, demonstrating little sensitivity to variations arising during the manufacturing process that can be automated through the use of standardised elements. The converter in question is compact in size and low in profile, being particularly useful in those applications which require both low power and low voltage, i.e. for supplying power to end loads.

Claims

1. **Magnetic integration of a planar inductor** (20) for a switched power converter including filtering means (14) connected directly to a load to supply it with a current having zero ripple; said planar inductor (20) comprising a magnetic core (23) formed by at least one section of an E type standardised core, a first coil (21) and a second coil (22) that are magnetically coupled to each other in order to obtain a leakage inductance (21-2); one end of said first coil (21) and the corresponding end of said second coil (22) being electrically connected at a common second node (24); **characterised** in that each of said first coil (21) and said second coil (22) is wound around a respective first and second outside leg of said standardised core section for conducting the common magnetic flux observed respectively by both the first coil (21) and the second coil (22) through the ferromagnetic circuit formed by said outside legs of said magnetic core (23).

2. **Magnetic integration of a planar inductor** (20) according to claim 1, **characterised** in that said first coil (21) has a number of turns that is different from the number of turns of said second coil (22).

3. **Magnetic integration of a planar inductor** (20) according to either one of claims 1 or 2, **characterised** in that the flux observed by said leakage inductance (21-2) is conducted through the ferromagnetic circuit formed by the centre leg and the outside leg on which said first coil (21) is wound.

4. **Magnetic integration of a planar inductor** (20) according to claim 3, **characterised** in that the magnitude of said leakage inductance (21-2) is limited by means of a predetermined first air gap (23-1) located in the centre leg of said magnetic core (23).

5. **Magnetic integration of a planar inductor** (20) according to claim 1, **characterised** in that the magnitude of the flux observed respectively by said first coil (21) and said second coil (22) is limited by means of a second air gap located, respectively, in said outside legs of said magnetic core (23), and being of a value less than that of said first air gap (23-1).

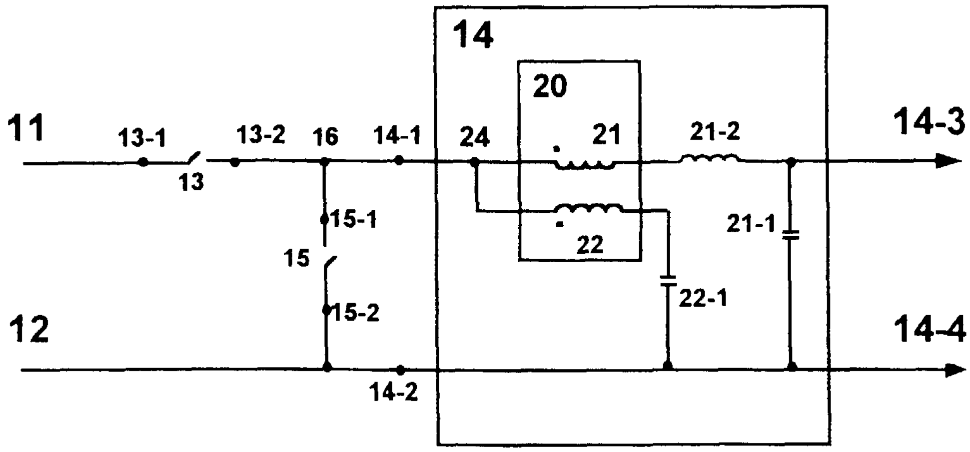
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FIG. 1

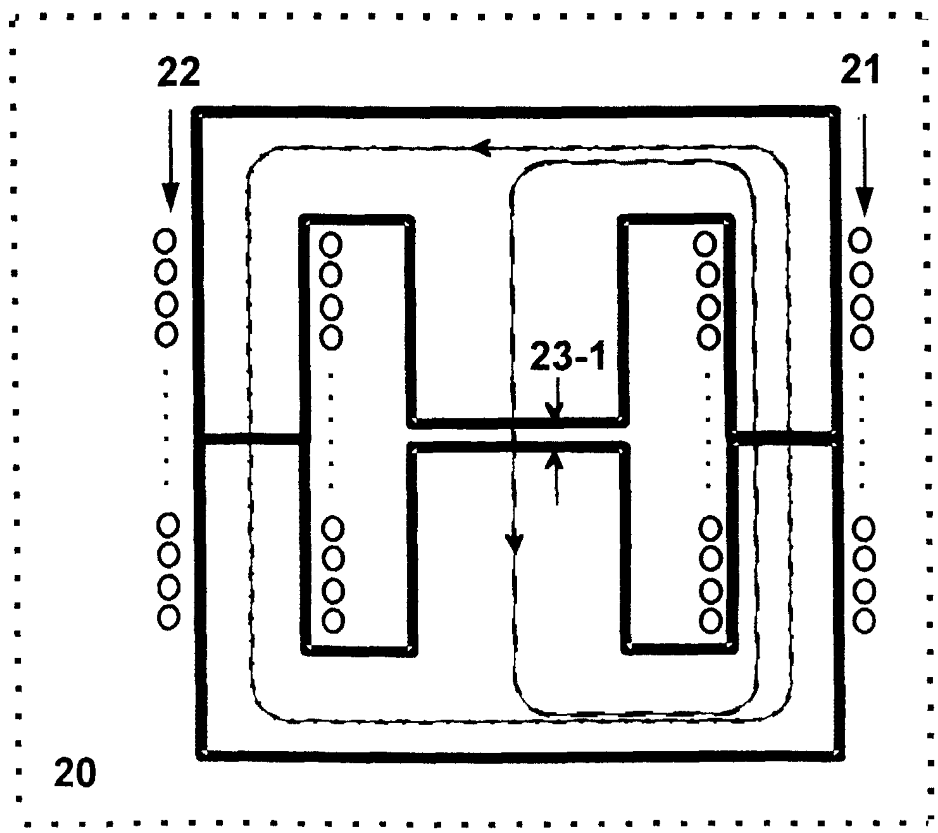
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FIG. 2

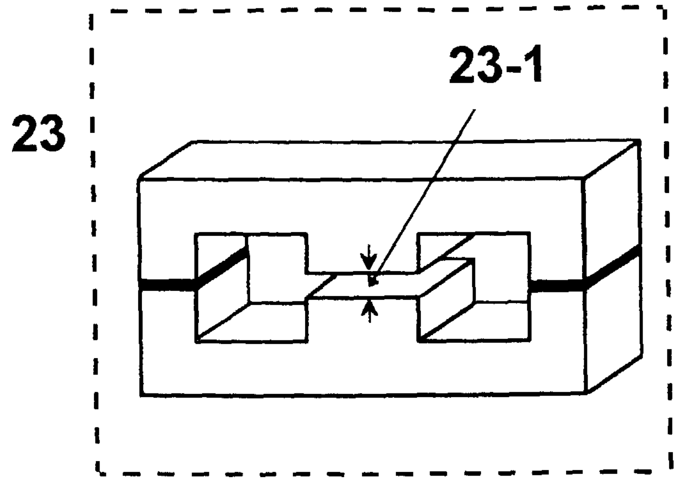

FIG. 3

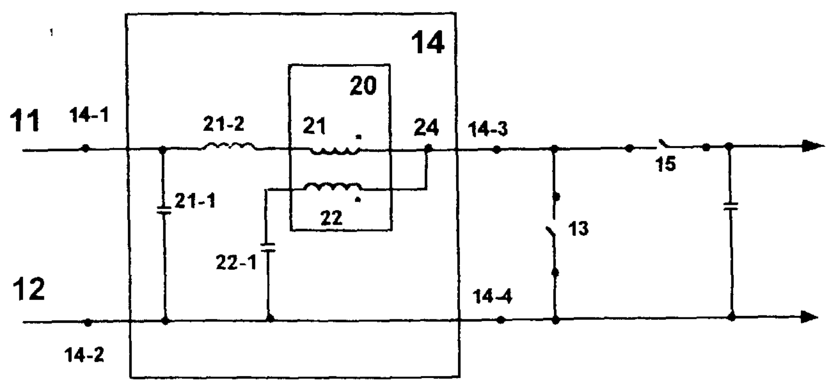

FIG. 4

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EUROPEAN SEARCH REPORT

Application Number
EP 99 40 2948

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 March 2000	Marti Almeda, R

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