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(54) Transformer arrangement

(57) The present invention relates to a transformer arrangement comprising a substrate (1) and a secondary winding formed by arranging the substrate with at least one conductive clamp (2) protruding from the substrate, the two ends of which clamp are connected by means of a conductor (3) in the substrate. The arrangement further comprises a primary winding (4) and a transformer core (7) arranged inside the primary winding, wherein a first electrically insulating structure (8) is arranged between the primary winding and the core.

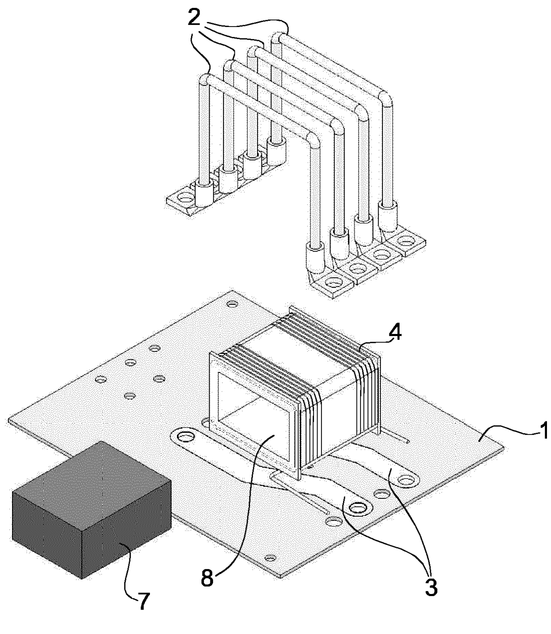

Fig. 2a

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Description

TECHNICAL FIELD

[0001] The invention relates to a transformer arrangement and a DC-DC converter comprising such a transformer arrangement.

BACKGROUND

[0002] DC-DC converters are commonly used to transform a DC voltage from one level to another. Switched DC-DC converters can be configured to decrease a high voltage to produce a lower voltage, or the other way around.

[0003] Important parameters for DC-DC converters include high efficiency, high reliability and high power density. High power density is particularly important in case space is limited, which is oftentimes the case in practical applications, such as in vehicles; for example in cars or trucks. By using a high switching frequency, volume reduction of passive components can be attained, thus resulting in a higher power density. However, the higher the switching frequency, the higher the switching loss of the converter. Typically, power MOSFETs are used to effect converter switching, and when turning the transistors on and off high voltage spikes, ringing and voltage overshoots occur, even though transistors with low on-resistance are used. Further, high switching frequency results in high stress and high EMI noise caused by parasitic components.

[0004] As can be seen, a number of combining factors adds up to the overall performance of a DC-DC converter. In order to provide a converter with high performance, a topology capable of higher switching frequency with higher efficiency should be selected. For this purpose, a so called LLC resonant topology is oftentimes used, where an LLC circuit as illustrated in Figure 1 shapes the voltage and current across the transistors so that the transistors switches when the voltage is zero, which is referred to as zero voltage switching (ZVS). Notwithstanding the fact that an LLC resonant topology is used, thermal management of the converter is essential, which in its turn is dependent on issues such as for instance packaging and mechanical and electrical design. Vehicle high-voltage DC busses are not fixed-voltage buses in the manner mains-connected buses are, and the ability of a vehicle DC-DC converter to accept a large input voltage range is thus important and practically requires good thermal characteristics of the converter transformer.

SUMMARY

[0005] An object of the present invention is thus to provide a transformer arrangement which solves or at least mitigates these problems in the art.

[0006] This objective is achieved in an aspect of the present invention by a transformer arrangement. The arrangement comprises a substrate and a secondary winding formed by arranging the substrate with at least one conductive clamp protruding from the substrate, the two ends of which clamp are connected by means of a conductor in the substrate. The arrangement further comprises a primary winding and a transformer core arranged inside the primary winding, wherein a first electrically insulating structure is arranged between the primary winding and the core.

[0007] The present invention is advantageous in that the conductors of the substrate, being for instance an insulated metal substrate, forms part of the secondary winding together with the clamp(s) attached to, and protruding from, the substrate. From a thermal point of view, the secondary winding will be very close to the underside of the substrate, where heat sinks typically will be arranged. Thus, by integrating the clamps with the substrate and conductors therein such that the secondary winding of the transformer is formed, good thermal dissipation is attained for the secondary winding and, indirectly, for the primary winding. A further advantage with having the secondary winding mounted directly to the substrate is that a low impedance electrical path is created to the rectifier stage. Advantageously, the transformer arrangement of the present invention results in design compactness and shorter signal paths, which reduces signal loss and further mitigates negative effects of electromagnetic interference (EMI).

[0008] In a further embodiment of the present invention, the transformer arrangement comprises enclosing means arranged in two physically separate parts, where each part comprises a core portion being arranged to extend inside the primary winding, and an enclosing portion being arranged to at least partly enclose the primary and secondary winding. The core portion is arranged to be located inside the second electrically insulating structure, which is located inside the primary winding, and further extends horizontally out of the primary winding and attaches to the second, enclosing portion. The respective enclosing parts are arranged to be joined with the other, wherein the core portions are arranged to face, and possibly even abut, each other inside the primary winding and the enclosing portions are arranged to jointly enclose the primary winding and the secondary winding. By having the enclosing portions of the transformer arrangement form a housing around the windings, the external leakage field is advantageously reduced, which in its turn reduces EMI and magnetic interference. Advantageously, by separating the enclosing means in two parts, the procedure of assembling the core and enclosing portions onto the primary winding is greatly facilitated.

[0009] In a further embodiment, a ferrite element is arranged between the primary winding and the secondary winding, on a second electrically insulating structure arranged between the primary winding and the secondary winding. This ferrite element is inserted between the windings in order to accurately control the leakage flux on the transformer primary side.

[0010] In yet a further embodiment two ferrite elements are used, each being integrated with the enclosing portion of the respective part of the transformer enclosing means. Advantageously, by separating the ferrite element into two physically different parts, and having each part integrated with the respective enclosing portion, a low resistance thermal path is created from the respective ferrite element, via the transformer enclosing means, to a heat sink. Further, by modifying the air gap between the two ferrite elements, the resonance frequency of an LLC circuit can be varied; the greater the gap, the smaller the inductance. A lower permeability material could also be used to create a distributed air gap. The permeability of the material and its physical shape (length and cross section) would then be chosen to create the desired leakage inductance. Such an approach would lead to decreased manufacturing costs, improved thermal management and a more compact design, since primary and secondary windings could be placed closer to the leakage flux without being affected by it.

[0011] In still another embodiment, the ferrite element is further arranged to press against the secondary winding with a third electrically insulating structure arranged between the ferrite element and the secondary winding, whereby a further low resistance thermal path is created from the leakage rod to the converter heat sink.

[0012] In a further embodiment, the first electrically insulating structure and the second electrically insulating structure are joined on two opposite sides by means of a respective electrically insulating supporting wall perpendicularly arranged with respect to the two structures, thereby forming a space where the primary winding can be inserted and enclosed. Thus, by having a box-like construction open at two sides where the primary winding and the first portion of the transformer core can be inserted and housed, the primary winding is galvanically insulated from the transformer core, the ferrite element and the secondary winding. In a further embodiment, the electrically insulating supporting walls are arranged to insulate the primary winding from the substrate.

[0013] In yet a further embodiment, the electrically insulating structure arranged between the primary winding and the core is arranged as an electrically insulting bobbin on which the primary winding is wound. This bobbin can be easily inserted and housed in the box-like construction defined in the previous embodiment.

[0014] In another embodiment of the present invention, thermally conductive pads are arranged between the primary winding and the substrate. Thus, a low thermal impedance path is provided from the primary winding to the converter heat sink.

[0015] It is noted that the invention relates to all possible combinations of features recited in the claims. Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. Those skilled in the art realize that different features of the present invention can be combined to create embodiments other than those described in the following.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The invention is now described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 shows the circuit diagram of a full-bridge LLC resonant DC-DC converter known in the art,

Figure 2a illustrates an embodiment of a transformer arrangement of the present invention in an exploded view,

Figure 2b illustrates the transformer arrangement of Figure 2a in assembled form,

Figure 3 illustrates a further embodiment of the present invention, where the transformer arrangement comprises enclosing means configured as two physically separate parts,

Figure 4 illustrates a further embodiment of the present invention, where a ferrite element is used for controlling leakage flux,

Figure 5 illustrates a further embodiment of the present invention, where two separate ferrite elements, integrated into the enclosing means are used for controlling leakage flux,

Figures 6 and 7 illustrate how components shown in the preceding figures are mounted to form a transformer arrangement according to an embodiment of the present invention,

Figures 8 and 9 show the transformer arrangement in cross section arranged on a substrate according to an embodiment of the present invention, and

Figure 10 shows the transformer arrangement mounted to a substrate according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0017] The invention will now be described more fully herein after with reference to the accompanying drawings, in which certain embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided by way of example so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

[0018] Figure 1 shows a full-bridge LLC resonant DC-

DC converter 30 known in the art. As such, it will not be described in any greater detail herein. The DC-DC converter is supplied with a DC voltage. In an exemplifying application of the present invention, where the DC-DC converter is used in a heavy truck, the input voltage is as high as 600V. The four transistors TA, TB, TC, TD, being e.g. power MOSFETS or insulated-gate bipolar transistors (IGBTs), forming an inverter stage 31 on a transformer primary side are controlled to switch the input DC voltage and produce a square-wave voltage ranging from +300V to -300V with a desired duty cycle.

[0019] An LLC converter has two resonant frequencies, an upper frequency determined by

$$fr_1 = \frac{1}{2\pi\sqrt{Lr * Cr}},$$

and a lower frequency determined by

$$fr_2 = \frac{1}{2\pi\sqrt{(Lr + Lm) * Cr}},$$

[0020] To achieve zero voltage switching, the converter should be designed to operate around the higher frequency fr_1. The transformer currents are almost sinusoidal at the resonant frequency, where gain is at unity and the switching efficiency of the transistors is at optimum. The output voltage is adjusted by changing the transformer gain which is done by increasing the switching frequency above the upper resonant frequency.

[0021] Now, a first AC voltage - i.e. the square-wave voltage produced between terminals AB and CD by the transistors, are converted by the LLC circuit 32 formed by Cr, Lr and Lm into a second AC voltage and its corresponding sinusoidal current. Thus, the LLC circuit acts as an AC filter supplying the transformer primary side with the second AC voltage. The transformer converts the second AC voltage to a third AC voltage of appropriate amplitude on its secondary side. Finally, a passive rectifier stage formed by diodes D1 and D2 and capacitor Cout converts the third AC voltage to a DC output to be delivered to a DC-DC converter load. An active rectifier stage could also advantageously be used in some implementations. In the exemplifying application for the present invention, the DC voltage delivered to a load is 28V. Thus, the DC-DC converter has converted a 600V input into a 28V output.

[0022] In the present invention, the topology used for the converter is exemplified in the form of LLC, but it is to be noted that other topologies also are possible.

[0023] Figures 2a and 2b illustrate an embodiment of the present invention, showing a transformer arrangement consisting of a primary winding 4, a transformer core 7 and a secondary winding. Figure 2a shows an exploded view of the transformer arrangement while Figure 2b shows an assembled transformer arrangement. The secondary winding is formed by arranging a substrate 1 with at least one conductive clamp, but preferably a plurality of clamps 2, the two ends of each respective clamp being connected by means of a conductor 3 in the form of a wiring in the substrate. The primary winding 4 of the transformer is arranged at a top side of the substrate. Further, the transformer core 7 is arranged inside the primary winding on a first electrically insulating structure 8 arranged between the primary winding and the core. As was discussed in connection to Figure 1, an LLC circuit 32 may in embodiments of the present invention be utilized to convert a first AC voltage to a second AC voltage on the transformer primary side, and a rectifier stage is utilized to convert a third AC voltage to a DC output voltage on the transformer secondary side. The components forming the rectifier stage, i.e. the two diodes D1 and D2 and the capacitor Cout, are located on the substrate 1. If the substrate used has favourable thermal characteristics, such as an Integrated Metal Substrate (IMS), life expectancy of the rectifier components increases, and permissible ripple current through the capacitor Cout can be increased. All or part of the components forming the LLC circuit 32, i.e. the series capacitor Cr, the inductance Lr and the parallel inductance Lm both provided by the transformer, may be located on substrate 1 but could alternatively be located on a separate substrate, which will be discussed in more detail later.

[0024] As has been previously discussed, the transformer arrangement illustrated in Figures 2a and 2b is advantageous in that the conductors 3 of the substrate 1, being for instance an insulated metal substrate, forms part of the secondary winding together with the clamps 2 attached to the substrate. From a thermal point of view, the secondary winding will be very close to the underside of the substrate, where heat sinks typically will be arranged. Thus, by integrating the clamps with the substrate and conductors therein such that the secondary winding of the transformer is formed, good thermal dissipation is attained for the secondary winding and, indirectly, for the primary winding. A further advantage with having the secondary winding mounted directly to the substrate is that a low impedance electrical path is created to the rectifier stage. Moreover, since the LLC circuit 32 and rectifier stage in embodiments of the present invention are arranged on the substrate, components - such as e.g. diodes and capacitors - are located close to the transformer, advantageously resulting in design compactness and shorter signal paths which reduces signal loss and further mitigates negative effects of electromagnetic interference (EMI). By placing the LLC circuit 32 and second power converters on the substrate, thermal management of the components will also improve effectively resulting in longer component endurance, which is particularly advantageous for converters used by manufacturers of heavy vehicles where usage of the present invention is envisaged.

[0025] As was mentioned hereinabove, the components of the LLC circuit 32 could either be integrated on the substrate 1 or be arranged on a separate substrate. With reference to Figure 1, it should be noted that the four power transistors are arranged on a separate substrate from that shown in Figures 2a and 2b. In an embodiment of the present invention, with respect to the LLC circuit 32, the series capacitor Cr is arranged on the substrate where the four power MOSFETS are arranged, whereas in a further embodiment of the present invention, the series capacitor Cr is arranged on the substrate 1.

[0026] To this end, in a further aspect of the invention, a DC-DC converter is provided, where the transformer arrangement as shown in Figures 2a and b (and different embodiments of which will be discussed in more detail in the following) is connected to the inverter stage 31 comprising the four transistors TA, TB, TC and TD in Figure 1, thereby creating the DC-DC converter 30, the circuit diagram of which is illustrated in Figure 1, with the thermal, mechanical and electrical advantages of the converter discussed in Figures 2a and b.

[0027] Figure 3 shows yet another embodiment of the present invention, where the transformer arrangement comprises enclosing means arranged in two physically separate parts 9, 10. Each part of the bipartite core comprises a respective core portion 7a, 7b extending into the primary winding 4, and further an enclosing portion 5a, 5b being arranged to at least partly enclose the primary and secondary winding. The core portion 7a, 7b rests on the first electrically insulating structure 8 located inside the primary winding and further extends horizontally out of the primary winding and attaches to the enclosing portion 5a, 5b. Thus, the core portion may act as a supporting shaft for the enclosing portion of the enclosing means. Advantageously, a distance is created between the substrate 1 and the second enclosing portion 5a, 5b. The enclosing means can hence rest on the first insulating structure 8 by using its core portion as a support while there is a distance between the enclosing portion and the substrate such that the enclosing means and substrate is galvanically insulated from each other. A further electrically insulating structure 6 may optionally be arranged to insulate the primary winding from the substrate. When the transformer arrangement is in operation, the respective enclosing means part 9, 10 abuts the other, and the two enclosing portions 7a, 7b, and optionally further the two core portions 5a, 5b, will be joined together. The primary and secondary winding will thus be enclosed by the two enclosing means parts 9, 10. The procedure of assembling the transformer core onto the primary winding is greatly facilitated by dividing the enclosing means in two parts. By having the enclosing portion of the transformer core forming a housing around the windings, the external leakage field is advantageously reduced, which in its turn reduces EMI and magnetic interference.

[0028] With reference to Figure 4, a ferrite element 11 referred to as a *leakage rod* is arranged between the primary winding 4 and the secondary winding 2 to control leakage flux. The leakage rod 11 is arranged on a second electrically insulating structure 12 arranged between the primary winding and the secondary winding. In yet another embodiment, the leakage rod 11 is designed to press against the secondary winding 2 with a third electrically insulating structure (not shown), arranged between the leakage rod 11 and the secondary winding 2, whereby a further low resistance thermal path is created from the leakage rod to a transformer arrangement heat sink.

[0029] Again with reference to Figure 4, in still another embodiment of the present invention, a box-like insulating structure is used, which is composed of the second insulating structure 12 joined on two opposite sides by means of a respective electrically insulating supporting wall 16, 17 perpendicularly arranged with respect to the second insulating structure. Advantageously, this box-like structure forms a space 18 enclosed by walls 16, 17, the first insulating structure 8 and the second insulating structure 12 where the primary winding 4 can be inserted and housed. Thus, by having the box-like construction open at two sides where the primary winding 4 and the core portion 7a, 7b of the enclosing means 9, 10 can be inserted and housed, the primary winding is galvanically insulated from the enclosing means, the leakage rod 11, the clamps 2, and the substrate 1 (effectively forming part of the secondary winding). The primary winding 4 is by means of this box-like structure enclosed from five directions. In a further embodiment shown in Figure 4, the first electrically insulating structure arranged between the primary winding 4 and the enclosing means 9, 10 is arranged as an electrically insulating bobbin 8 on which the primary winding is wound. This bobbin can be easily inserted and housed in the box-like construction defined in the previous embodiment.

[0030] Figure 5 illustrates a further embodiment of the present invention, where two leakage rods 11a, 11b are used (leakage rod 11b is only visible from this view in cross section but is identical in structure to leakage rod 11a), each leakage rod being integrated with the enclosing portion of the respective part 9, 10 of the enclosing means. Further shown in Figure 5 are the conductive clamps 2 that form the secondary winding together with the substrate (not shown in Figure 5) and the box-like construction composed of the second insulating structure 12, the insulating structure embodied by walls 16, 17 and the first insulating structure 8. The electrically insulating first structure 8 comes in the form of a bobbin on which the primary winding is wound, and which isolates the primary winding from the core portions 7a, 7b of the respective enclosing means 9, 10, which core portions are inserted into, and housed in, the bobbin. Advantageously, by separating the leakage rod into two physically different parts and integrating the respective rod with the enclosing portions of the enclosing means, a low resistance thermal path is created from the leakage rods, via the enclosing means, to a converter heat sink. Moreover, in an embodiment of the invention, the electrically insulating structure 6, referred to as the fourth insulating structure, is used to insulate the primary winding 4 from the substrate 1.

[0031] Figures 6 and 7 further illustrate how the different components illustrated in the preceding figures are mounted to form a transformer arrangement. Figure 6 illustrates how the clamps 2 are fitted to the electrically insulating and supporting walls 16, 17 of the box-like structure inside of which the bobbin 8 and the primary winding 2 (not shown) subsequently will be arranged. First, one of the enclosing means parts 9 are assembled and fastened onto the walls 16, 17. Then, with reference to Figure 7, the second of the enclosing means parts 10 are assembled and fastened onto the walls 16, 17. The two enclosing means parts are joined at section S-S. In an embodiment of the invention, the electrically insulating supporting walls 16, 17 are arranged to insulate the primary winding 4 from the substrate 1.

[0032] Figures 8 and 9 show the transformer arrangement in cross section arranged on a substrate 1 comprising a variety of components including the rectifier stage and least parts of the LLC circuit. Thus, shown mounted on the substrate are the two enclosing means parts 9, 10, which comprises the enclosing portions 5a, 5b, the leakage rods 11a, 11b and the core portions 7a, 7b extending into the first insulating structure 8 embodied in the form of a bobbin. It should be noted that the air gap between the two leakage rods can be altered to affect the resonance frequency of the previously discussed LLC converter. Further shown are the clamps 2 which form the secondary winding together with the substrate (and conductors in the substrate connecting the two ends of the respective clamp).

[0033] Figure 10 shows how the transformer assembly 26 shown in the previous figures can be mounted to the substrate 1. Directly arranged onto the substrate is a gap pad 20 for improving thermal conductivity between the substrate and the transformer assembly mounted onto it. On top of the gap pad is a fixture 21 for housing a cooling clamp 22 and further for fixating the respective end of the primary winding. Thereafter, a further sil pad 23 is arranged and a cooling plate 24 for further contributing to thermal management. A final gap pad 25 is inserted before the transformer arrangement 26 is mounted to the substrate 1. Thus, in an alternative embodiment, parts or all of these components forms an insulating structure for insulating the primary winding (not shown) from the substrate 1.

[0034] In yet a further embodiment, substrate 1 of the transformer arrangement is being arranged with a conductive underside that can be used instead of conductive wiring, which in that case must be provided with insulating means insulating the conductive underside against a heat sink on which the substrate will be located. Advantageously, this underside can be used both for its thermal properties and as a very good conduit for electricity, for example replacing a low voltage negative rail (B-).

[0035] Even though the invention has been described with reference to specific exemplifying embodiments thereof, many different alterations, modifications and the like will become apparent for those skilled in the art. The described embodiments are therefore not intended to limit the scope of the invention, as defined by the appended claims.

Claims

1. A transformer arrangement comprising:

a substrate (1);
a secondary winding formed by arranging the substrate with at least one conductive clamp (2) protruding from the substrate, the two ends of which clamp are connected by means of a conductor (3) in the substrate;
a primary winding (4); and
a transformer core (7) arranged inside the primary winding, wherein a first electrically insulating structure (8) is arranged between the primary winding and the core.

2. The transformer arrangement of claim 1, further comprising enclosing means arranged to be physically divided in two parts (9, 10), each part comprising:

a core portion (7a, 7b) being arranged to extend inside the primary winding (4);
and
an enclosing portion (5a, 5b) being arranged to at least partly enclose the primary and secondary winding (2), wherein
the core portion is arranged to be located inside the first electrically insulating structure (8), which is located inside the primary winding, and further extends horizontally out of the primary winding and attaches to the enclosing portion;
and
the respective enclosing means part is arranged to be joined with the other,
wherein the second portions are arranged to jointly enclose the primary winding and the secondary winding.

3. The transformer arrangement of claim 2, further comprising:

two ferrite elements (11a, 11b), each being integrated with the enclosing portion (5a, 5b) of the respective part (9, 10) of the enclosing means, said ferrite elements implementing a resonant inductance (L_r).

4. The transformer arrangement of any one of claims 1 or 2, further comprising:

   a ferrite element (11) arranged between the primary winding (4) and the secondary winding (2), which ferrite element is arranged on a second electrically insulating structure (12) arranged between the primary winding and the secondary winding.

5. The transformer arrangement of any one of claims 3 or 4, wherein the ferrite element (11) further is arranged to press against the secondary winding (2) with a third electrically insulating structure arranged between the ferrite element and the secondary winding.

6. The transformer arrangement according to any one of claims 3-5, the ferrite elements (11, 11a, 11b) being arranged such that a distributed air gap is provided.

7. The transformer arrangement according to claim 6, the ferrite elements (11, 11a, 11b) being formed from a low-permeability material, thereby facilitating provision of the distributed air gap.

8. The transformer arrangement of any one of the preceding claims, further comprising a fourth electrically insulating structure (6) arranged to insulate the primary winding (4) from the substrate (1).

9. The transformer arrangement of any one of claims 4-7, wherein the first electrically insulating structure (8) and the second electrically insulating structure (12) are joined on two opposite sides by means of a respective electrically insulating supporting wall (16, 17) perpendicularly arranged with respect to the two structure, thereby forming a space (18) where the primary winding (4) is inserted and enclosed.

10. The transformer arrangement of claim 9, wherein said electrically insulating supporting walls (16, 17) are arranged to insulate the primary winding (4) from the substrate (1).

11. The transformer arrangement of any one of the preceding claims, wherein the first electrically insulating structure (8) arranged between the primary winding (4) and the core (7a, 7b) is arranged as an electrically insulating bobbin on which the primary winding is wound.

12. The transformer arrangement of any one of the preceding claims, further comprising:

   thermally conductive pads separating the primary winding (2) and the substrate (1).

13. The transformer arrangement according to any one of the preceding claims, the substrate (1) further being arranged with a conductive underside and electrically insulating means insulating the conductive underside.

14. The transformer arrangement of any one of the preceding claims, further comprising a rectifier stage arranged on the substrate (1) for converting a secondary side AC voltage to a DC voltage.

15. The transformer arrangement of any one of the preceding claims, further comprising an LLC circuit (32) arranged on the substrate (1), said LLC circuit (32) comprising a resonant capacitor (C_r) and a resonant inductance (L_r) arranged in series with the transformer primary winding.

16. A DC-DC converter comprising the transformer arrangement of any one of claims 14-15 and further comprising:

   an inverter stage (31) arranged to be connected to the transformer arrangement, to receive a DC voltage input to the DC-DC converter and to convert said DC input voltage to an AC voltage supplied to said LLC circuit (32).

17. The DC-DC converter of claim 16, wherein the inverter stage comprises a full-bridge inverter (31).

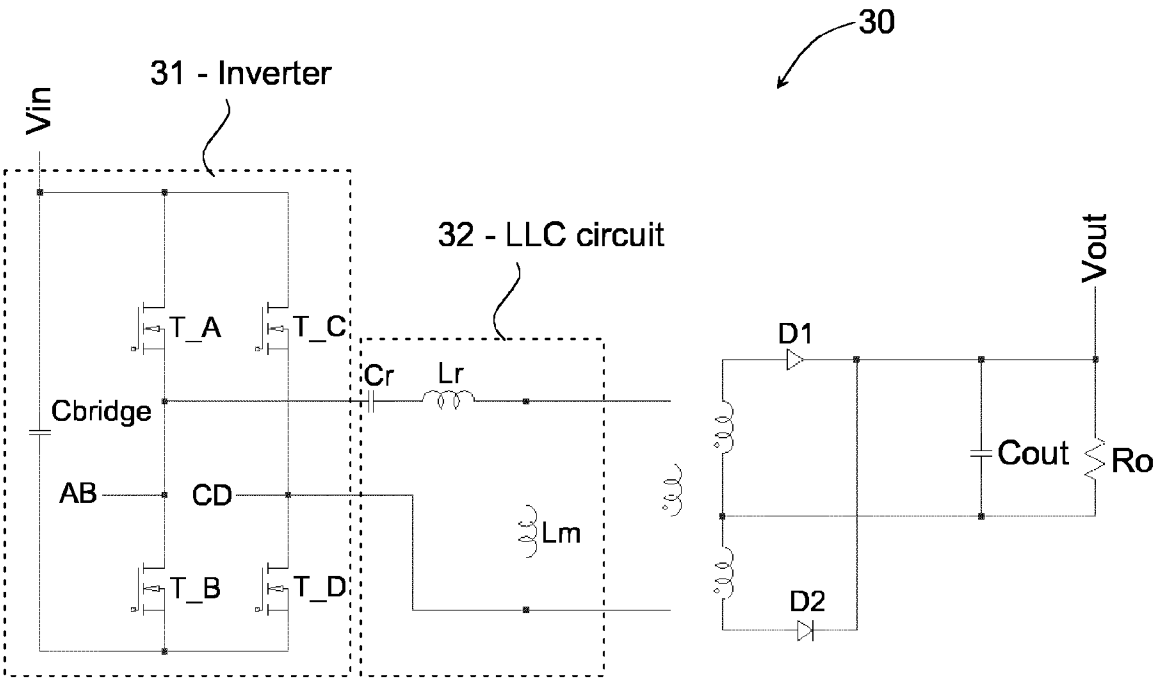
30
31 - Inverter
Vin
32 - LLC circuit
Vout
T_A
T_C
Cr
Lr
D1
Cbridge
Cout
Ro
AB
CD
Lm
T_B
T_D
D2

Fig. 1

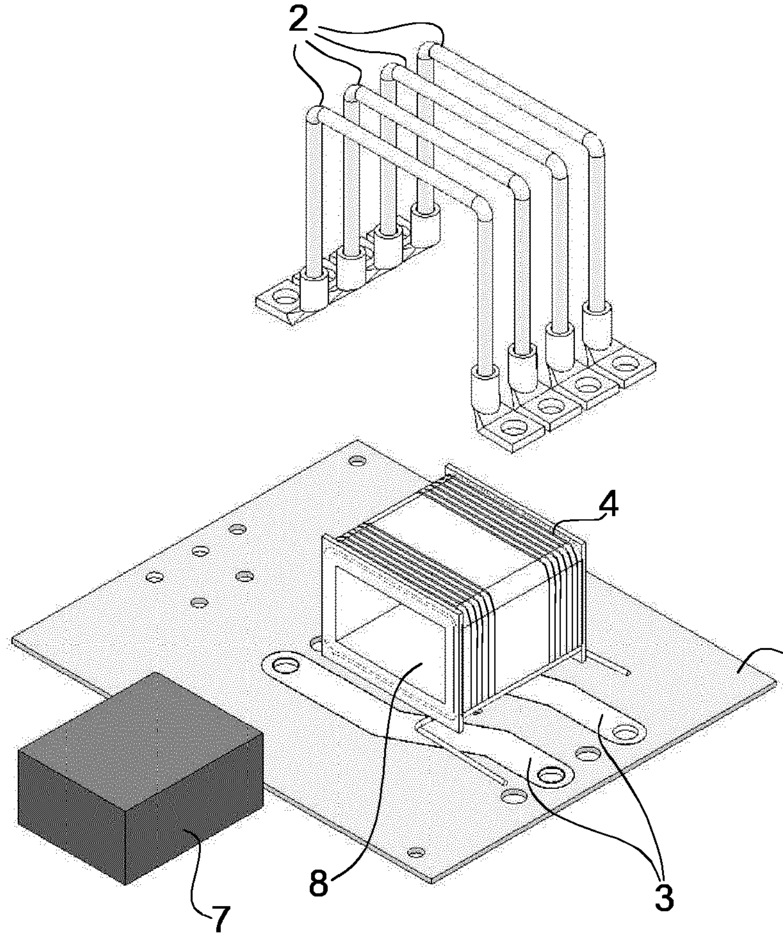

Fig. 2a

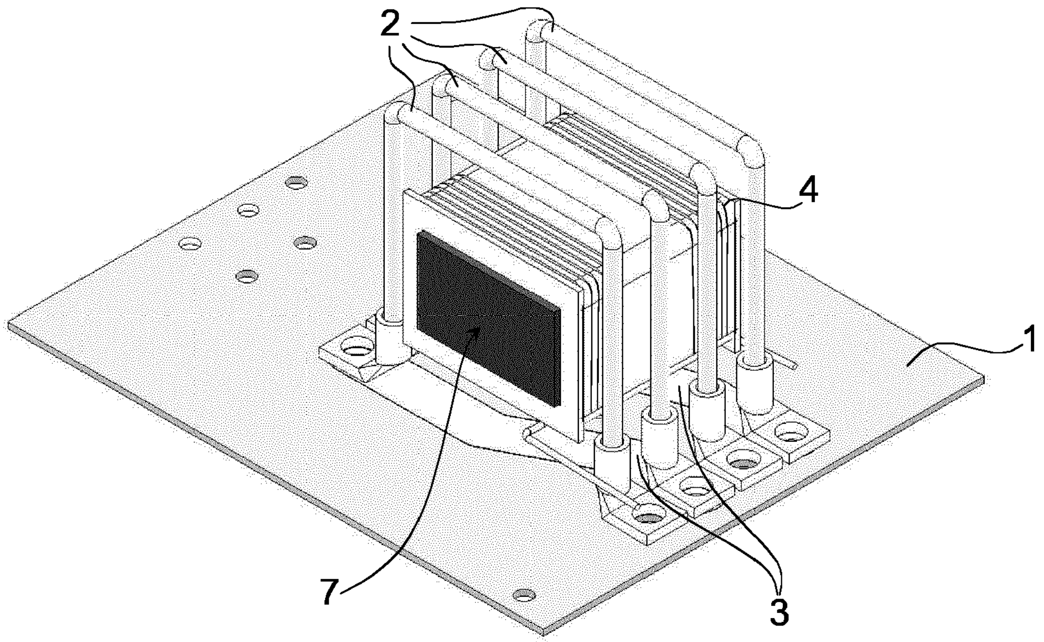

Fig. 2b

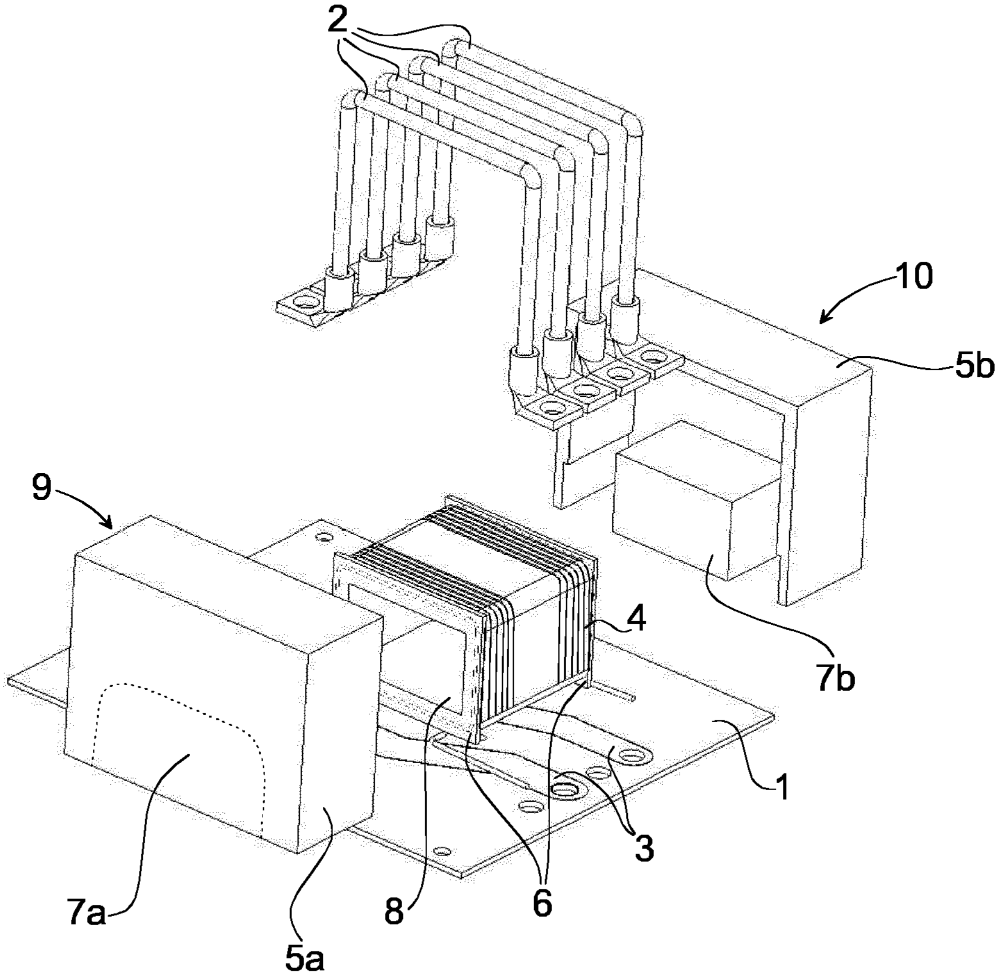

Fig. 3

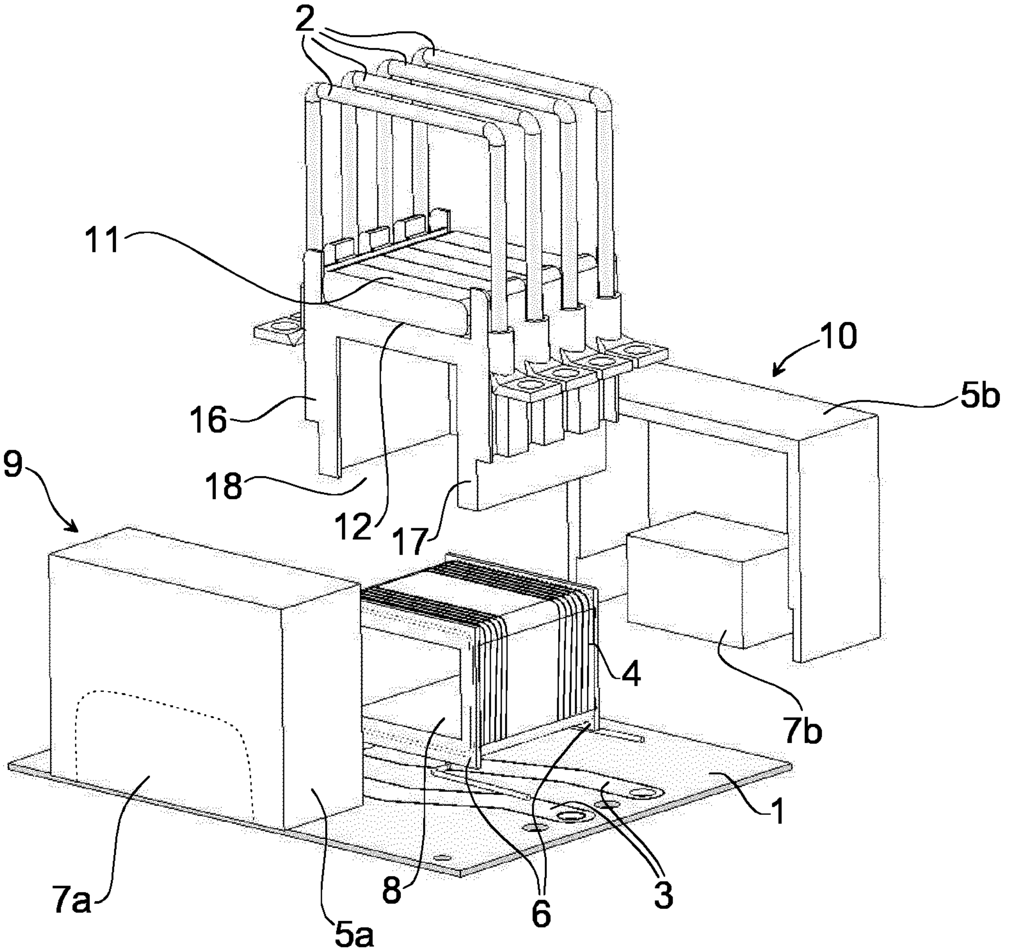

Fig. 4

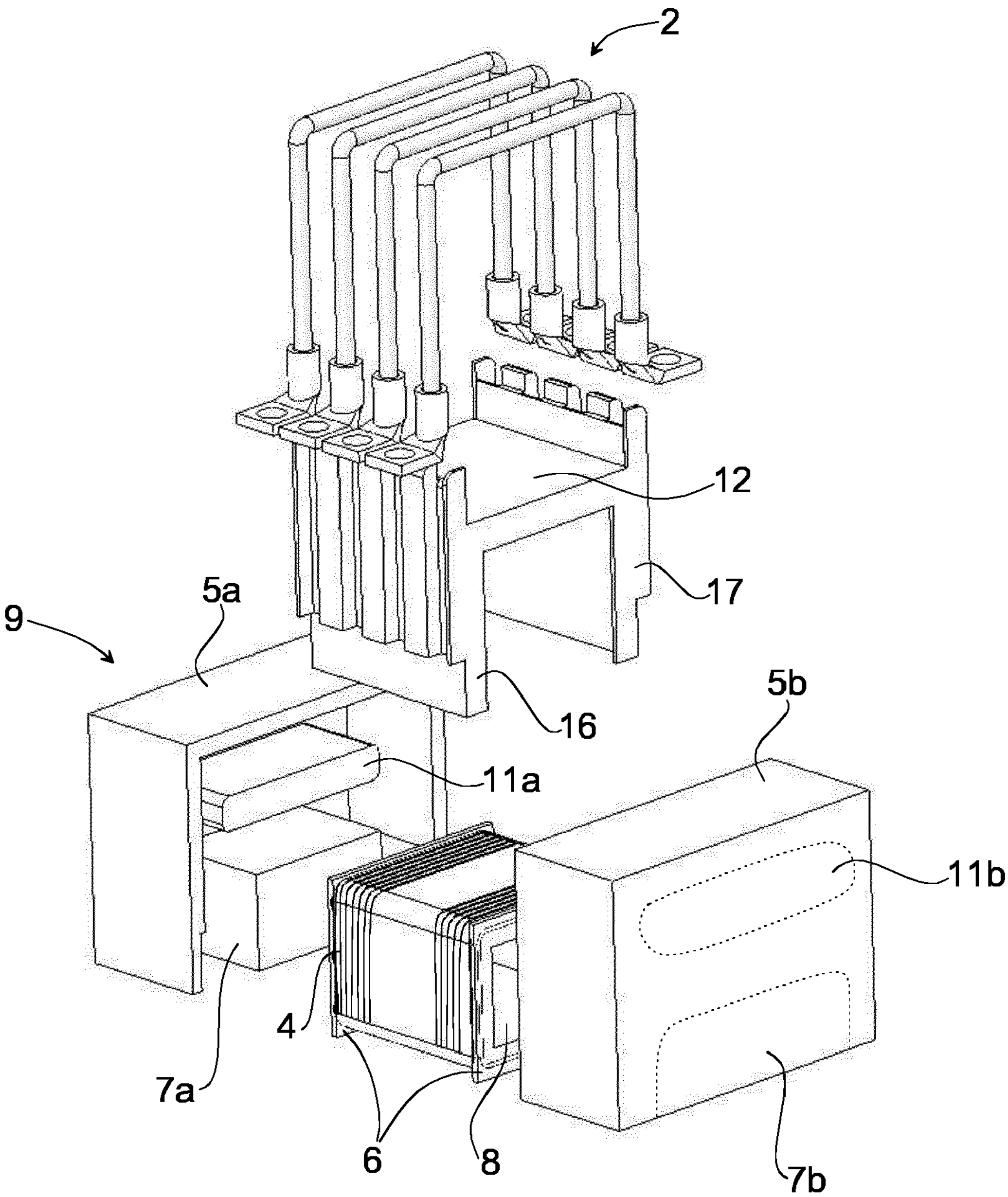

Fig. 5

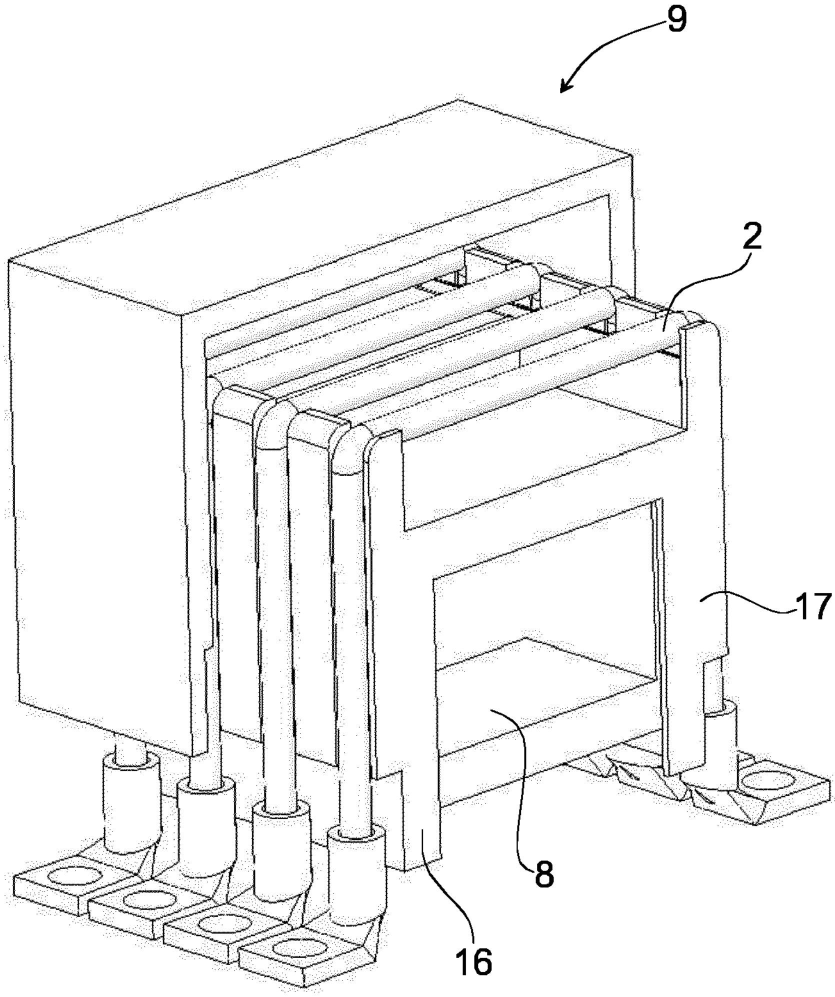

Fig. 6

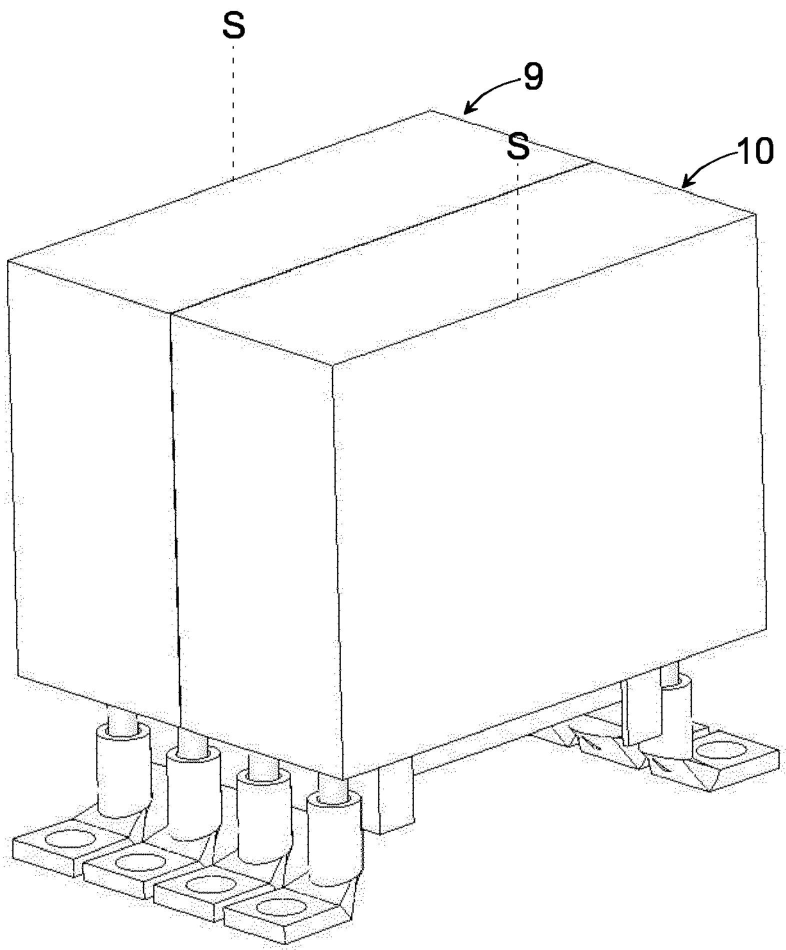

Fig. 7

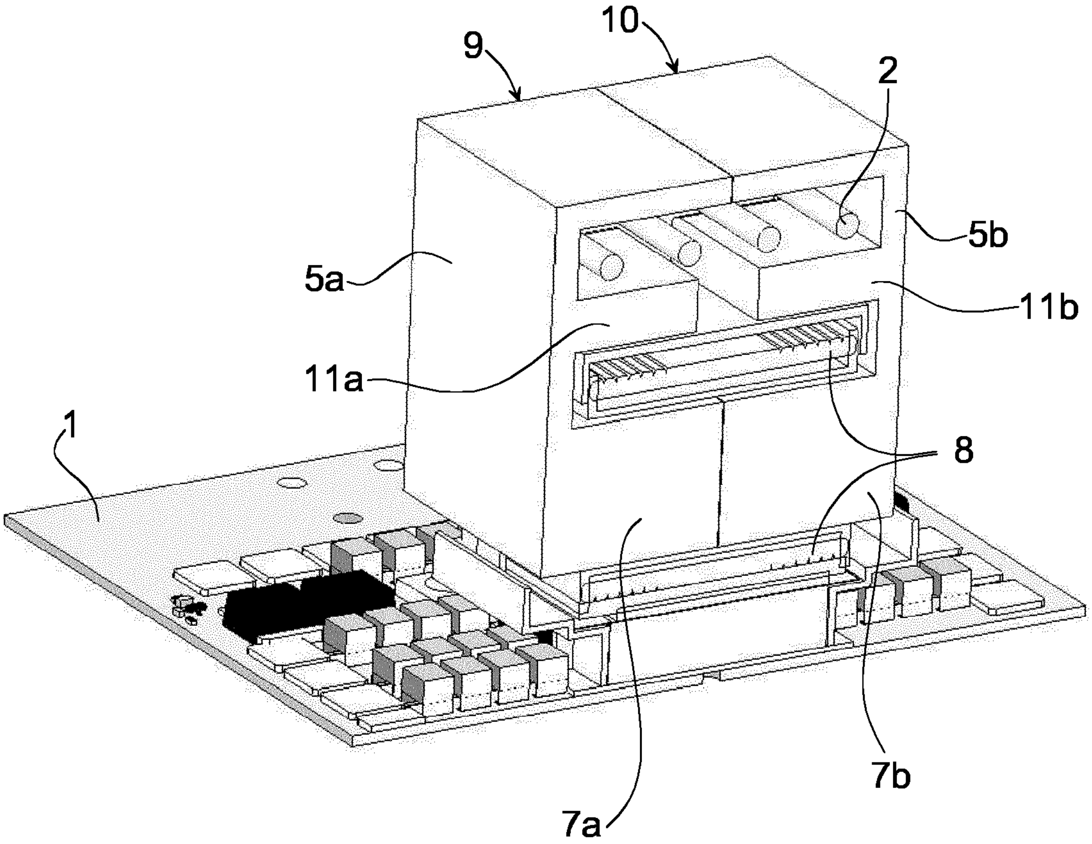

Fig. 8

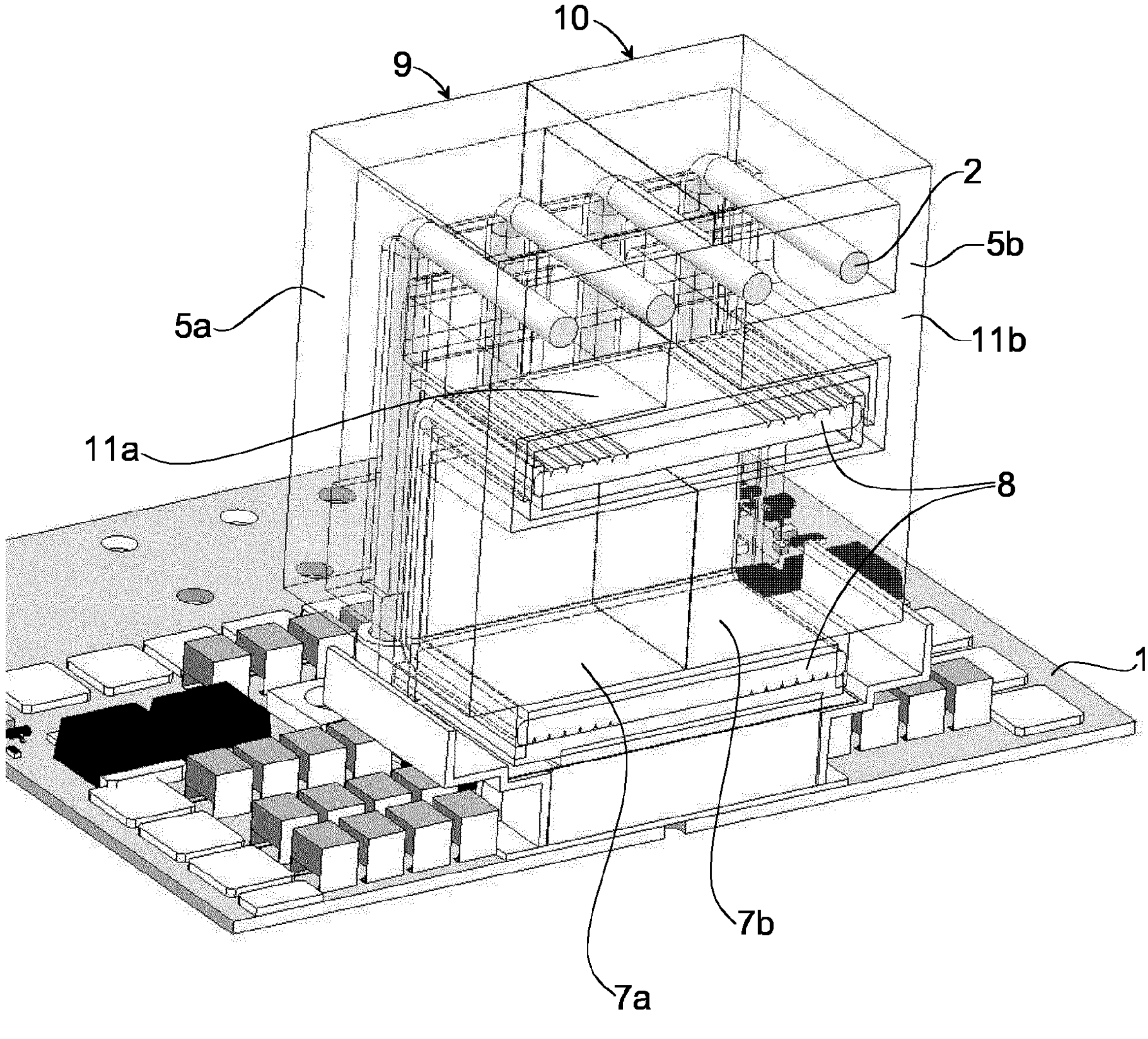

Fig. 9

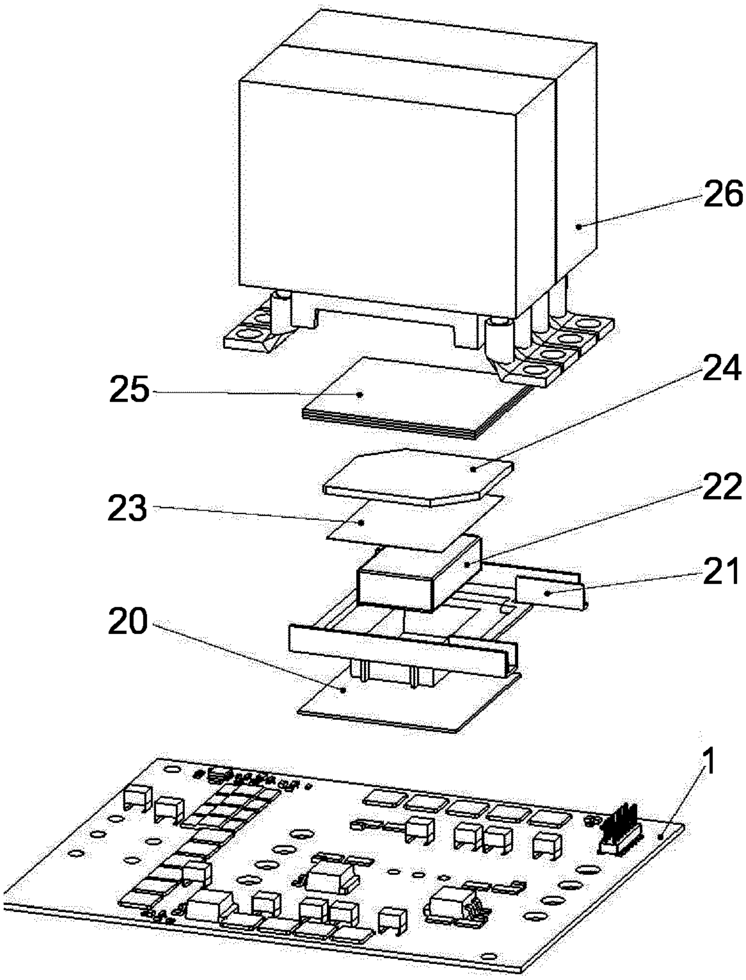

Fig. 10

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 12 15 6536

DOCUMENTS CONSIDERED TO BE RELEVANT

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
Munich	14 August 2012	Gols, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 12 15 6536

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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