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10121 Torino (IT)**(54) PRINTED CIRCUIT BOARD PROVIDED WITH AN INTEGRATED INDUCTOR DEVICE**

(57) A printed circuit board (1) having: at least one insulating plate (3) provided with a plurality of conductive tracks (4) defining respective electrical conductors; and an inductor device (2), which is supported by the insulating plate (3), is electrically connected to the conductive tracks (4) and has a toroidal magnetic core (6) and at least one coil (8) arranged around the toroidal magnetic core (6). The inductor device (2) has a plurality of conductive rigid bars (9), which are "U"-shaped, are arranged astride the toroidal magnetic core (6) and each have two

straight legs (10) connected to one another by a cusp (11). The insulating plate (3) has a plurality of through holes (5), each engaged by an end of a corresponding leg (10) of a conductive bar (9). The insulating plate (3) has conductive tracks (4), which connect the legs (10) of the conductive bars (9) so as to create an electrical circuit, which is part of the inductor device (2) and closes the conductive bars (9) around the toroidal magnetic core (6) so as to define respective turns of the coil (8).

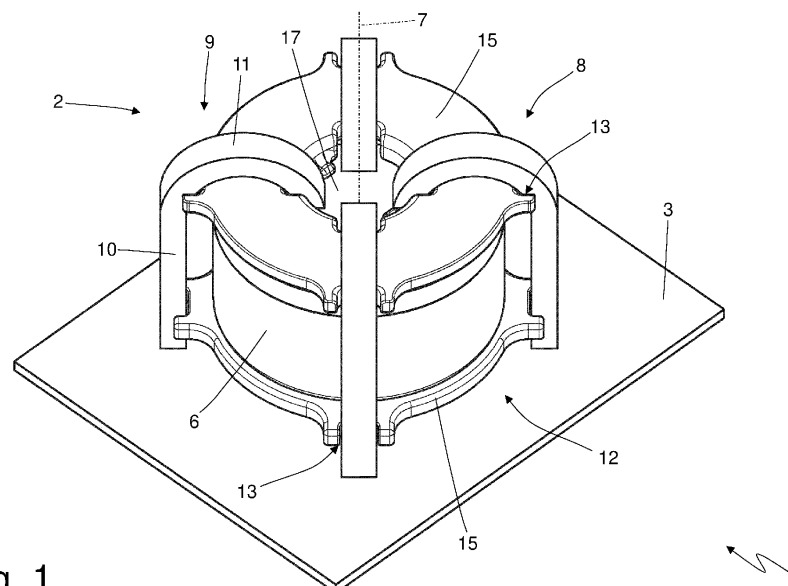


Fig. 1

Description

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This Patent Application claims priority from Italian Patent Application No. 102021000024580 filed on September 24, 2021.

TECHNICAL SECTOR

[0002] The invention relates to a printed circuit board provided with an integrated inductor device.

PRIOR ART

[0003] A rotary electric machine for automotive drive is controlled by an electronic power converter, which generally has an AC side connected to the terminals of the stator winding of the rotary electric machine and a DC side connected to the power storage system.

[0004] In order to comply with electromagnetic pollution regulations and in order to avoid electromagnetic interferences with other elements present on board the vehicle, the electronic power converter has to be provided with passive filters (often low-pass filters) to stop the propagation of "*electromagnetic noise*". The creation of these filters involves the use of inductor devices.

[0005] However, the electric currents affecting the electronic power converter controlling the rotary electric machine for automotive drive can reach relatively high intensities (in the range of several dozens of amperes and up to one hundred amperes) and, hence, finding available inductor devices that are already ready and capable of bearing these electric currents becomes difficult, if not impossible. Furthermore, those inductor devices capable of bearing said electric currents are large-sized and require, in order to be connected to the rest of the circuit, connectors that significantly increase the weight and the overall dimensions of the electronic power converter.

[0006] Patent applications CN202178142U, DE102016210746A1, EP1071103A1, JPH03133109A and US2010253459A1 disclose a printed circuit board provided with an integrated inductor device.

DESCRIPTION OF THE INVENTION

[0007] The object of the invention is to provide a printed circuit board provided with an integrated inductor device, which has a small weight, is small-sized and, at the same time, is easy and economic to be manufactured.

[0008] According to the invention, there is provided a printed circuit board provided with an integrated inductor device according to the appended claims.

[0009] The appended claims describe preferred embodiments of the invention and form an integral part of the description.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The invention will now be described with reference to the accompanying drawings, showing a non-limiting embodiment thereof, wherein:

- figure 1 is an upper perspective rear view of a printed circuit board provided with an integrated inductor device according to the invention;
- figure 2 is a perspective view of the inductor device of figure 1;
- figure 3 is an exploded perspective view of the inductor device of figure 1;
- figure 4 is a lower view of an insulating plate of the printed circuit board of figure 1; and
- figure 5 is a schematic sectional view of a detail of the printed circuit board of figure 1.

PREFERRED EMBODIMENTS OF THE INVENTION

[0011] In figure 1, number 1 indicates, as a whole, a printed circuit board provided with an integrated inductor device 2. The printed circuit board 1 is used to manufacture an electronic power converter for a rotary electric machine for automotive drive.

[0012] The printed circuit board 1 comprises (at least) an insulating plate 3 provided with a plurality of conductive tracks 4 (shown in figure 4) defining respective electrical conductors. Furthermore, the insulating plate 3 has a series of through holes 5 (shown in figure 5) with a rectangular shape, which are arranged in the area of respective conductive tracks 4; a conductive track 4 preferably surrounds a respective through holes 5 on all sides, if necessary widening around the through hole 5.

[0013] As shown in figures 2 and 3, the inductor device 2 is supported by the insulating plate 3 and is electrically connected to the conductive tracks 4 in the area of the through holes 5. The inductor device 2 comprises a toroidal magnetic core 6, which has a central symmetry axis 7 arranged perpendicularly to the insulating plate 3, and (at least) a coil 8 arranged around the toroidal magnetic core 6.

[0014] The inductor device 2 comprises a plurality of conductive rigid bars 9, which are "U"-shaped and each have two straight legs 10 connected to one another by a circular cusp 11; namely, each conductive bar 9 is shaped like a "U-bolt", since it has the shape of an upside-down "U" (with the two straight legs 10 facing the insulating plate 3). Each conductive bar 9 is arranged astride the toroidal magnetic core 6 so that a leg 10 is arranged on the outside of the toroidal magnetic core 6 and the other leg 10 is arranged on the inside of the toroidal magnetic core 6. The end of each leg 10 of a conductive bar 9 is inserted in a respective through hole 5 (namely, engages a respective through hole 5) and is welded to the conductive track 4 surrounding the corresponding through hole 5.

[0015] The conductive tracks 4, which connect the legs

10 of the conductive bars 9, create an electrical circuit, which is part of the inductor device 2 and closes the conductive bars 9 around the toroidal magnetic core 6 so as to define respective turns of the coil 8. Namely, each turn of the coil 8 surrounding the toroidal magnetic core 6 for 360° consists, for the main part, of a "U"-shaped conductive bar 9 and consists, for the remaining part, of a piece of conductive track 4, which "closes" the ring.

[0016] The inductor device 2 comprises a support body 12, which is made of an electrically insulating material (namely, of a typically moulded plastic material) and houses the toroidal magnetic core 6. The support body 12 preferably engages, without a significant clearance, a central hole of the toroidal magnetic core 6 so that it cannot make any relative movement relative to the toroidal magnetic core 6.

[0017] According to a preferred embodiment, the support body 12 has a plurality of seats 13 and 14, which are "U"-shaped and engage respective legs 10 of the conductive bars 9, namely which house, on the inside, the legs 10 of the conductive bars 9 closing the legs 10 on three sides. In particular, the support body 12 has a plurality of outer seats 13, which engage respective legs 10 arranged on the outside of the toroidal magnetic core 6, and a plurality of inner seats 14, which engage respective legs 10 arranged on the inside of the toroidal magnetic core 6.

[0018] According to a preferred embodiment, the support body 12 comprises two circular end plates 15, which are arranged at the two opposite ends of the support body 12, and an intermediate tubular element 16, which is oriented perpendicularly to the two circular plates (15) and connects the two circular plates 15 to one another. The two circular plates 15 of the support body 12 rest against two opposite base surfaces of the toroidal magnetic core 6, whereas the intermediate tubular element 16 is arranged inside the central hole of the toroidal magnetic core 6, namely engages (substantially without a significant clearance) the central hole of the toroidal magnetic core 6.

The outer seats 13 are obtained in the two circular end plates 15 and are preferably manufactured as radial extensions of the two circular end plates 15.

[0019] According to a preferred embodiment shown in the accompanying figures, the support body 12 comprises a filling element 17, which is inserted inside the intermediate tubular element 16 (namely, is inserted at the centre of the toroidal magnetic core 6) and fills the entire empty space left free by the legs 10 of the conductive bars 9. The inner seats 14 are partly obtained in the intermediate tubular element 16 and partly obtained in the filling element 17 (as shown in the accompanying figures); alternatively, the inner seats 14 are obtained in the sole intermediate tubular element 16 or in the sole filling element 17.

[0020] According to a preferred embodiment, the support body 12 comprises two halves, which can be separated longitudinally, namely along a direction parallel to

the central symmetry axis 7 of the toroidal magnetic core 6, and are connected to one another through mechanical interlocking. In this way, the support body 12 is built by locking the two halves to one another with the magnetic core 6 in between; in particular, the joining of the two halves of the support body 12 takes place in the area of the intermediate tubular element 16.

[0021] According to a preferred embodiment, the support body 12 is directly and exclusively carried by the conductive bars 9 and is arranged at a distance other than zero from the insulating plate 3. Namely, the support body 12 is suspended from the conductive bars 9, which are engaged by the seats 13 and 14 of the support body 12.

[0022] In the embodiment shown in the accompanying figures, one single insulating plate 3 is provided; when the intensity of the electric current flowing through the conductive tracks 4 of the insulating plate 3 exceeds given values, instead of further thickening the insulating plate 3 (and, hence, the conductive tracks 4 obtained in the insulating plate 3), a plurality of insulating plates 3 on top of one another are preferably used, said plurality of insulating plates 3 being identical to one another and electrically connected to one another in parallel (there can be up to ten-twelve insulating plates 3 on top of one another). When there is a plurality of insulating plates 3 on top of one another, each leg 10 of a conductive bar 9 is arranged through a plurality of through holes 5, which are aligned with and overlap one another and are obtained through said plurality of insulating plates 3.

[0023] According to a possible embodiment shown in figure 5, there can be a plurality of metal tubes 18, each arranged through a through hole 5 of the insulating plate 3, provided with a collar resting against a conductive track 4 of the insulating plate 3 and crossed by a leg 10 of a conductive bar 9. The function of the metal tubes 18 is that of increasing the contact surface between a leg 5 and the corresponding conductive track 4 to which the leg 5 is welded, so as to reduce electrical contact resistance.

[0024] According to the embodiment shown in the accompanying figures, the conductive tracks 4 of the insulating plate 3 connect the legs 10 of the conductive bars 9 so as to create two coils 8, which are independent of one another and each affect half the conductive bars 9, so that inductor device 2 is a common mode inductor. According to a different embodiment which is not shown herein, the conductive tracks 4 of the insulating plate 3 connect the legs 10 of the conductive bars 9 so as to create one single coil 8 affecting all conductive bars 9.

[0025] The embodiments described herein can be combined with one another, without for this reason going beyond the scope of protection of the invention.

[0026] The printed circuit board 1 described above has numerous advantages.

[0027] First of all, the inductor device 2 integrated in the printed circuit board 1 described above is small-sized and has a small weight.

[0028] Furthermore, the inductor device 2 integrated in the printed circuit board 1 described above is easy and economic to be manufactured, since it only consists of a limited number of pieces, which can singularly be produced easily and are simple to be assembled together (even in an automatic manner), substantially constituting an interlocking system.

[0029] Finally, the inductor device 2 integrated in the printed circuit board 1 described above supports very intense electric currents, as the electrical conductors substantially consist of rigid bars (which can easily be manufactured, even with a large cross section), which are bent so as to be "U"-shaped.

LIST OF THE REFERENCE NUMBERS OF THE FIGURES

[0030]

- | | | |
|----|------------------------------|----|
| 1 | integrated circuit | 20 |
| 2 | inductor device | |
| 3 | insulating plate | |
| 4 | conductive tracks | |
| 5 | through holes | |
| 6 | toroidal magnetic core | 25 |
| 7 | central symmetry axis | |
| 8 | coil | |
| 9 | conductive bars | |
| 10 | legs | |
| 11 | cusps | 30 |
| 12 | support body | |
| 13 | inner seats | |
| 14 | outer seats | |
| 15 | plates | |
| 16 | intermediate tubular element | 35 |
| 17 | filling element | |
| 18 | metal tubes | |

Claims

1. A printed circuit board (1) comprising:

at least one insulating plate (3) provided with a plurality of conductive tracks (4) defining respective electrical conductors; and
an inductor device (2), which is supported by the insulating plate (3), is electrically connected to the conductive tracks (4) and comprises a toroidal magnetic core (6) and at least one coil (8) arranged around the toroidal magnetic core (6); the printed circuit board (1) is **characterized in that:**

the inductor device (2) comprises a plurality of conductive rigid bars (9), which are "U"-shaped and each have two straight legs (10) connected to one another by a cusp (11);

each conductive bar (9) is arranged astride the toroidal magnetic core (6) so that a leg (10) is arranged on the outside of the toroidal magnetic core (6) and the other leg (10) is arranged on the inside of the toroidal magnetic core (6);
the insulating plate (3) has a plurality of through holes (5), each engaged by an end of a corresponding leg (10) of a conductive bar (9); and
the conductive tracks (4) of the insulating plate (3) connect the legs (10) of the conductive bars (9) so as to create an electrical circuit, which closes the conductive bars (9) around the toroidal magnetic core (6) so as to define respective turns of the coil (8).

2. The printed circuit board (1) according to claim 1, wherein the inductor device (2) comprises a support body (12), which is made of an electrically insulating material and houses the toroidal magnetic core (6).

3. The printed circuit board (1) according to claim 2, wherein the support body (12) engages a central hole of the toroidal magnetic core (6).

4. The printed circuit board (1) according to claim 2 or 3, wherein the support body (12) has a plurality of seats (13, 14), which are "U"-shaped and engage respective legs (10) of the conductive bars (9).

5. The printed circuit board (1) according to claim 2 or 3, wherein the support body (12) has a plurality of outer seats (13), which are "U"-shaped and engage respective legs (10) arranged on the outside of the toroidal magnetic core (6), and a plurality of inner seats (14), which are "U"-shaped and engage respective legs (10) arranged on the inside of the toroidal magnetic core (6).

6. The printed circuit board (1) according to claim 5, wherein the support body (12) comprises:

two circular end plates (15), which are arranged at the two opposite ends of the support body (12); and
an intermediate tubular element (16), which is oriented perpendicularly to the two circular plates (15) and connects the two circular plates (15) to one another.

7. The printed circuit board (1) according to claim 6, wherein:

the two circular plates (15) of the support body (12) rest against two opposite base surfaces of the toroidal magnetic core (6); and
the intermediate tubular element (16) is ar-

ranged inside the central hole of the toroidal magnetic core (6).

8. The printed circuit board (1) according to claim 6 or 7, wherein the outer seats (13) are obtained in the two circular end plates (15). 5
9. The printed circuit board (1) according to claim 8, wherein the outer seats (13) are manufactured as radial extensions of the two circular end plates (15). 10
10. The printed circuit board (1) according to one of the claims from 2 to 9, wherein the support body (12) is fixed to the conductive bars (9) so as to be arranged at a distance other than zero from the insulating plate (3). 15
11. The printed circuit board (1) according to one of the claims from 2 to 10, wherein the support body (12) comprises two halves, which can be separated longitudinally, namely along a direction parallel to a central symmetry axis (7) of the toroidal magnetic core (6), and are connected to one another through mechanical interlocking. 20
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12. The printed circuit board (1) according to one of the claims from 2 to 11, wherein the support body (12) comprises a filling element (17), which is inserted at the centre of the toroidal magnetic core (6) and fills the entire empty space left free by the legs (10) of the conductive bars (9). 30
13. The printed circuit board (1) according to one of the claims from 1 to 12 and comprising a plurality of insulating plates (3) on top of one another, which are identical to one another and are electrically connected to one another in parallel. 35
14. The printed circuit board (1) according to claim 13, wherein each leg (10) of a conductive bar (9) is arranged through a plurality of through holes (5), which are aligned with and overlap one another and are obtained through said plurality of insulating plates (3). 40
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15. The printed circuit board (1) according to one of the claims from 1 to 14 and comprising a plurality of metal tubes (18), each arranged through a through hole (5) of the insulating plate (3), provided with a collar resting against a conductive track (4) of the insulating plate (3) and crossed by a leg (10) of a conductive bar (9). 50

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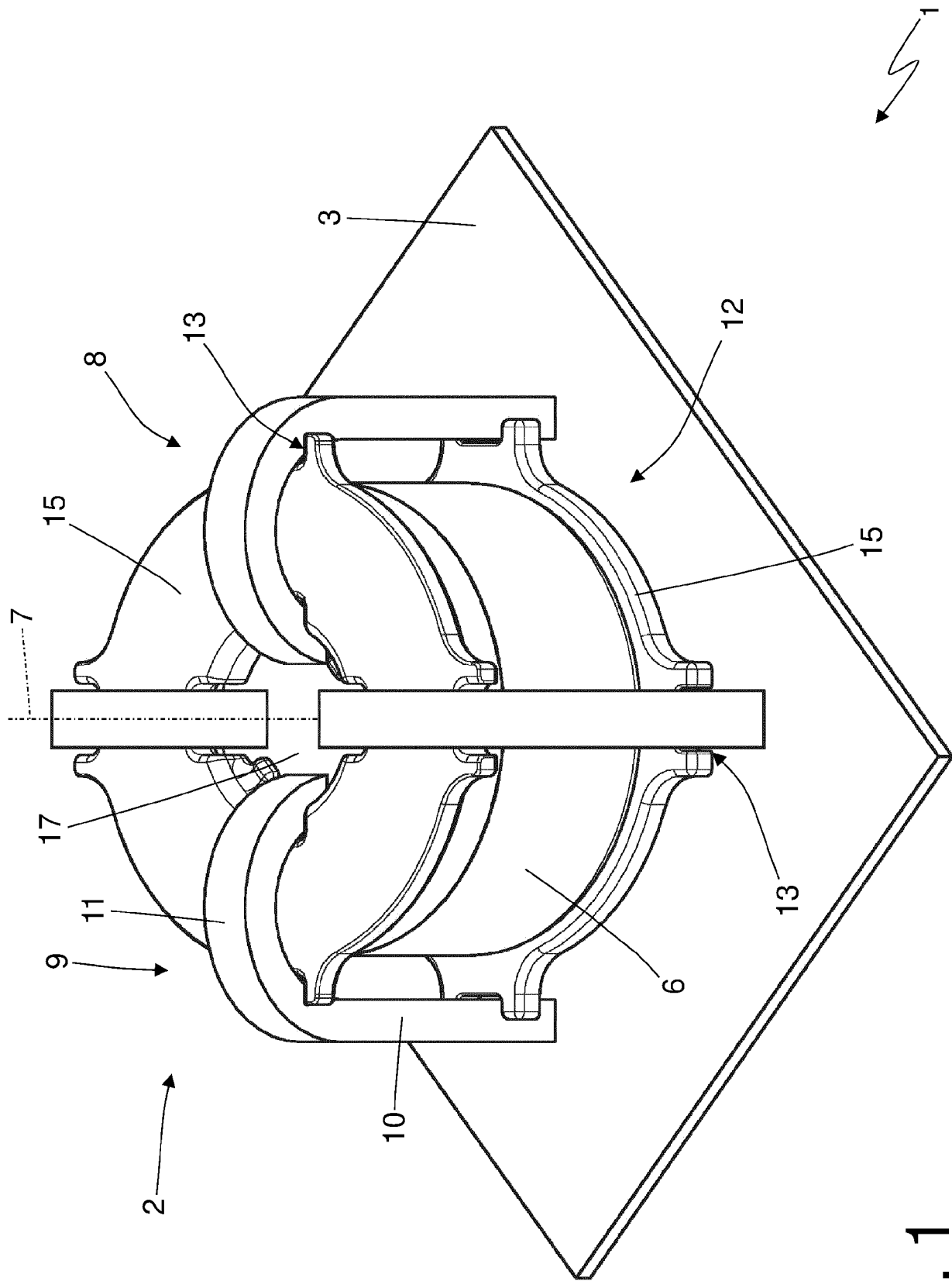


Fig. 1

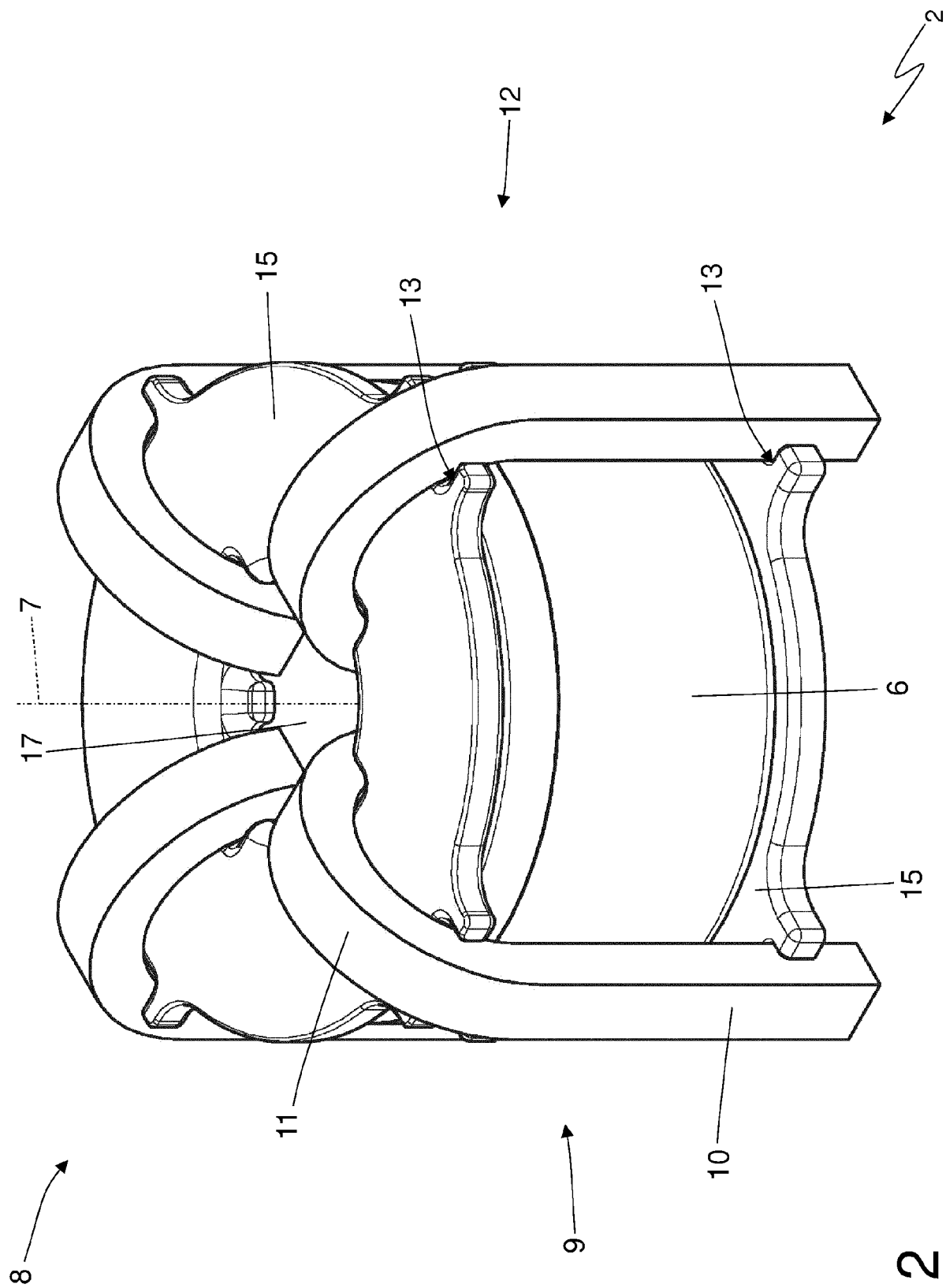
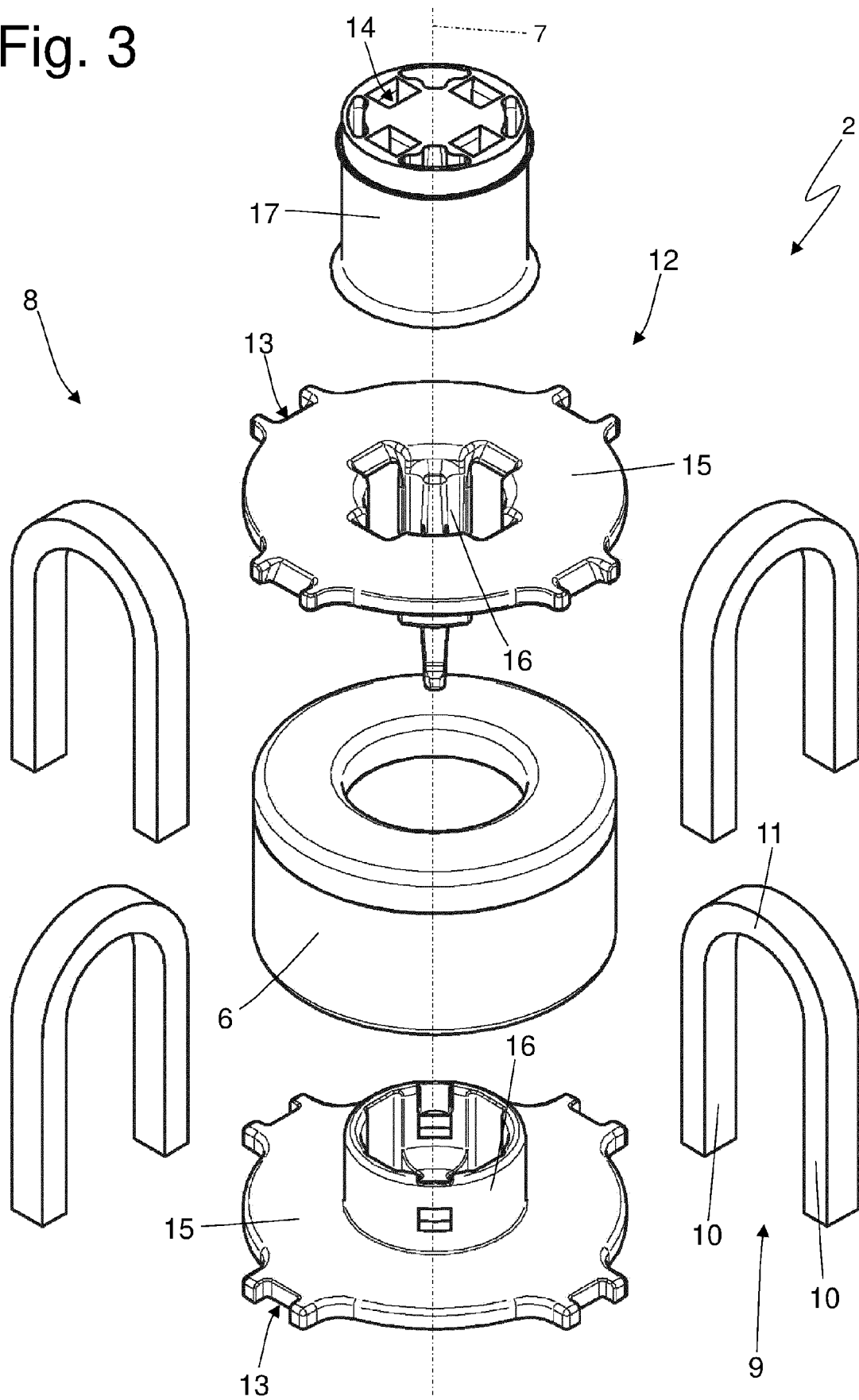


Fig. 2

Fig. 3



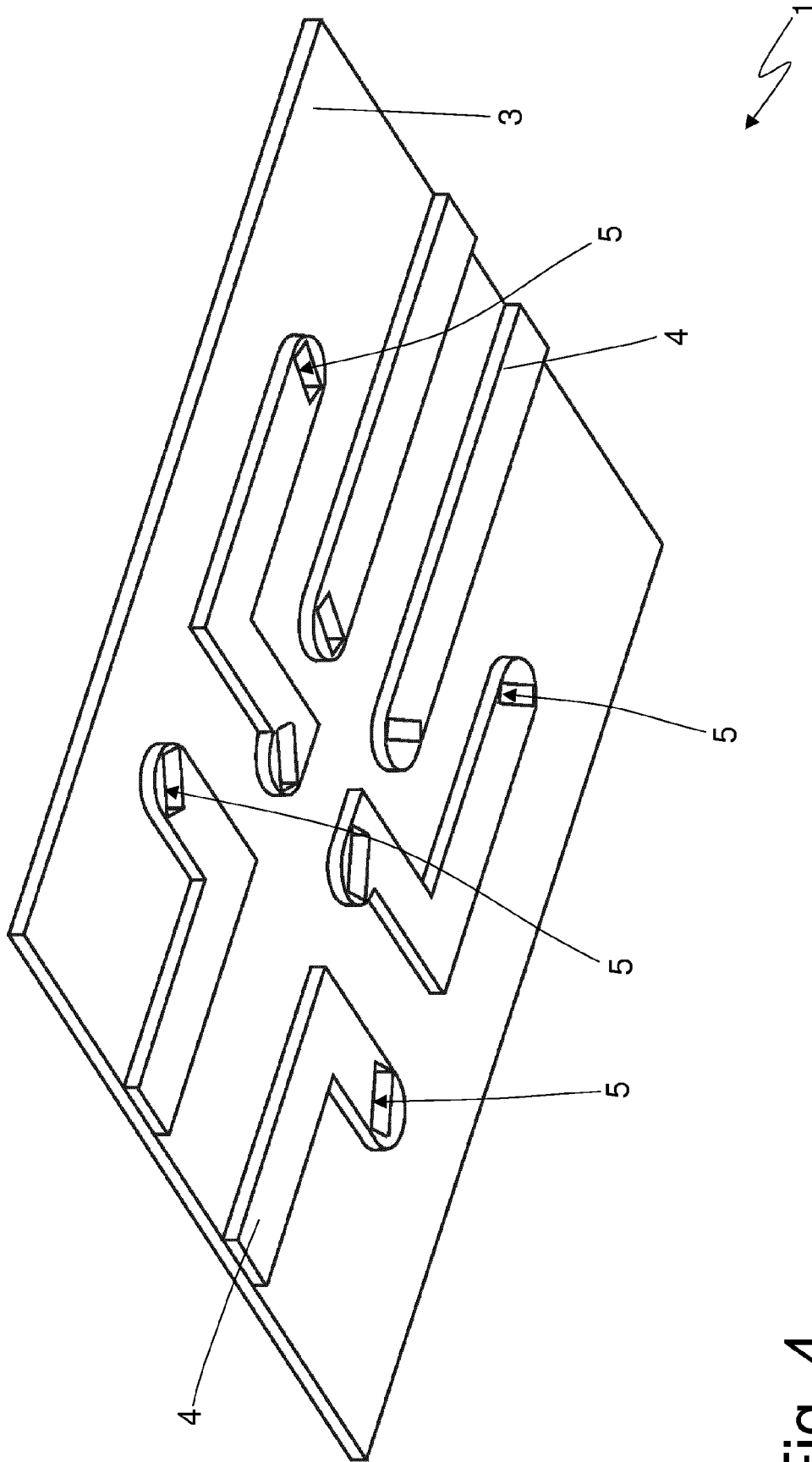


Fig. 4

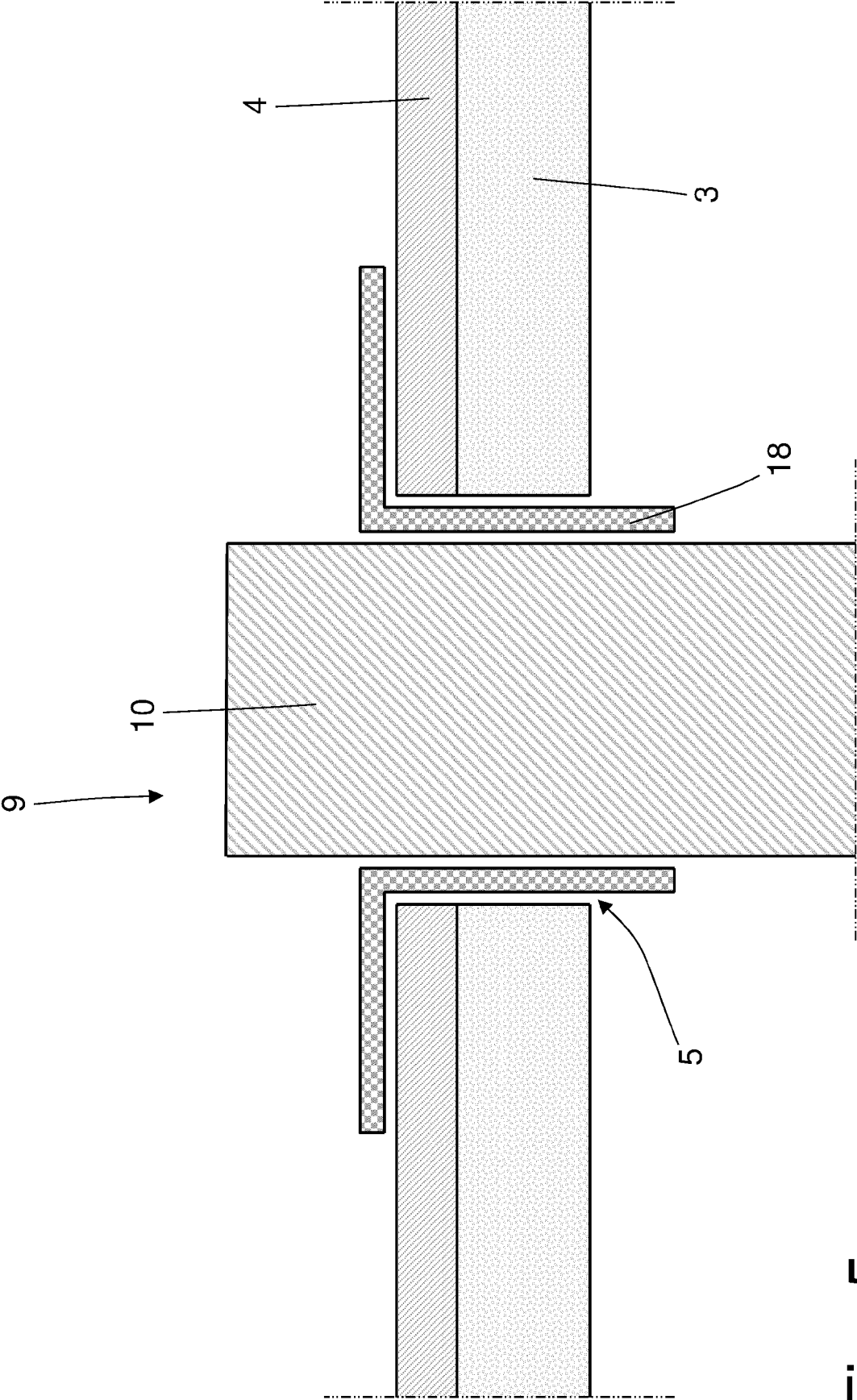


Fig. 5



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Application Number

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Munich		15 February 2023	Rouzier, Brice
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X : theory or principle underlying the invention Y : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : technological background O : non-written disclosure P : intermediate document & : member of the same patent family, corresponding document			



EUROPEAN SEARCH REPORT

Application Number

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