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(54) **INDUCTIVE DEVICE**

(57) An inductive device (1) comprising at least one PCB (2) with at least one pair of main portions (11, 12), each main portion being connected to the other portions by folding lines (9, 9') and having a through opening (13). The PCB comprises at least one track (15) electrically continuous and extending along the rims of the openings and passing by each one of the main portions. The PCB (2) has plate state, and an operational state wherein:
- the PCB is folded such that each main portion is rotated about folding lines with respect to the adjacent portions,
- each main portion of each pair forming an angle greater than zero with an adjacent portion of the PCB distinct from said pair, and
- the openings defining together a casing (20) able to accommodate a magnetic piece to be inductively coupled to windings formed by the track.

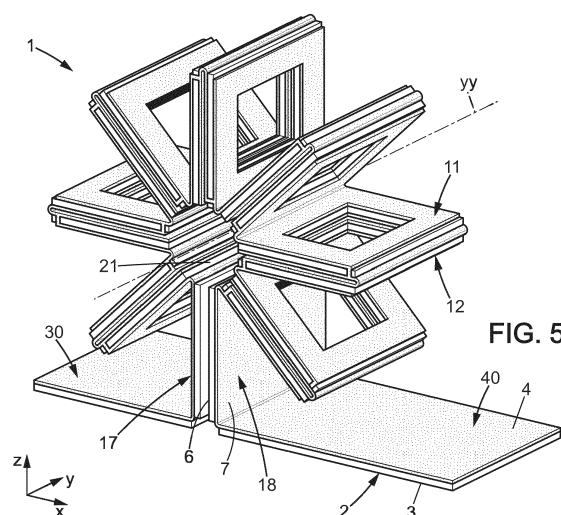


FIG. 5

Description

[0001] The invention pertains to the technical field of the energy. More specifically, the invention is related to an inductive device and an assembly containing such a device, to convert energy between electric and magnetic forms. The invention is also related to a process to manufacture such an assembly.

[0002] Usually, inductors or transformers for power electronics applications, for example to support at least 1 kilowatt, are made of discrete components. Such components can be surface-mounted, through-hole, or connected manually with cables. These components have a low level of integration and are expensive, difficult to cool, and require manual intervention.

[0003] A large part of integrated inductors or transformers include a planar architecture. The components with a planar architecture generally have the following limitations:

- a poor copper filling, due to few turn numbers and/or a small copper section,
- high copper losses, due to direct current (DC), high-frequency effects and combination of skin effect, proximity of the components and air gap, and
- a poor copper cooling.

[0004] In addition, the integrated inductors and transformers are difficult to cool.

[0005] Other structures include embedded toroid architectures for which one dimension of the magnetic material needs to be inferior to the thickness of a printed circuit board (PCB; i.e. typically less than 2 or 3 millimeters). Such architectures are therefore only limited to applications in the Watt level or less.

[0006] The invention improves the situation.

[0007] The applicant proposes an inductive device comprising at least one printed circuit board, the printed circuit board comprising N pairs of main portions, wherein N is an integer superior or equal to 1, each main portion being connected to the other portions by folding lines, each main portion having a through opening forming a path in a thickness direction of said main portion. The printed circuit board comprises at least one track electrically continuous and extending along the rims of the openings and passing by each one of the main portions. The printed circuit board has an inactive state wherein the printed circuit board has a plate shape, and an operational state wherein:

- the printed circuit board is folded such that each main portion is rotated about folding lines with respect to the adjacent portions,
- each main portion of each pair forming an angle with an adjacent portion of the printed circuit board distinct from said pair, the angle being strictly greater than zero, and
- the openings defining together a casing able to ac-

commodate a magnetic piece to be inductively coupled to windings formed by the track.

[0008] Such a device is adapted to at least kilowatt levels (current of several amperes) with high efficiency (few losses), low magnetic section, low mass, small and adapted size and form, and easy to cool. Such inductive devices are especially adapted to be embedded into an electronic assembly.

[0009] The inductive device can comprise the following features, separately or in combination one with the others:

- The track extends on at least two distinct layers of the printed circuit board. The printed circuit board comprises Vertical Interconnect Access interconnecting parts of the track between the at least two distinct layers. This enables to obtain more windings on a single portion of PCB and to reduce the volume of the inductive device.
- The two main portions of each pair are adjacent one to the other and connected one to the other by a folding line. The two main portions of each pair are superimposed one against the other by a complete folding about said folding line in the operational state. This enables to obtain lot of pairs with a single PCB produced.
- The two main portions of each pair are connected one to the other by an intermediate portion. The intermediate portion is connected respectively to each one of the main portions of said pair by a respective folding line such that to have an angle between said two main portions in the operational state of the printed circuit board. The intermediate portion further comprises a part of the track such that to ensure continuity of said track from one to the other said main portions of said pair. This enables to dispose a material, including air, between the two portions of a pair to enhance the cooling.
- The main portions are aligned substantially along a first direction in the inactive state of the printed circuit board such that said folding line are oriented into a second direction perpendicular to the first direction. This facilitates the PCB production. For example, a plate can comprise a plurality of parallel PCB. Then the PCB are separated one from the others along the main direction. Such a production can be easily automated.
- Each pair of main portions comprises M turns of the track around the openings, where M is comprised between 1 and 20. The form and the size of the inductive device can be easily adapted in function of the application.

- The track comprises a wire embedded inside the printed circuit board. This enables to have large section of conductive elements to support high power while having small size of the inductive device.
- The inductive device includes N pairs of main portions, wherein N is superior or equal to 2. This enables to adapt properties of the inductive device only by adapting the number of pairs.
- The pairs are similar one to another such that each pair forms a pattern and the pattern is N-replicated. This enables to easily adapt the design or the layout of an inductive device by using an already designed pattern.
- The sizes of the main portions of each pair are different from other pair and mutually adapted such that the device has a substantially elongated tridimensional form in the operational state. When the inductive device is integrated in an assembly, this enables to use any available volume to increase the inductive efficiency.
- The printed circuit board further comprises portions arranged to form legs and/or claws in the operational state to fix the device to other components. Such printed circuit board can be connected easily to various other elements.
- At least one of said portions arranged to form legs and/or claws has a through opening and a part of the track extending along the rims of said opening, such that said opening defines in part the casing and said part of the track forms at least partially a loop around said casing. Such legs and/or claws can have both a mechanical function and an inductive function.
- The printed circuit board further comprises portions arranged to conjointly form a housing in the operational state to receive a thermal conductive material and/or the magnetic piece. Such a PCB can also have protection function, for example from dust and liquid,
- The printed circuit board further comprises a thermal conductive member arranged to be disposed in a central opening of an annular magnetic piece. This enables to use a space, which is useless for inductive properties, to enhance the cooling of the device.
- The printed circuit board further comprises portions including a combination of metallic tracks able to conduct heat toward a predefined area arranged to be in contact with a heat sink. Said tracks and the electrical track can be produced in a common process step.

[0010] In a second aspect of the invention, the applicant proposes an inductive assembly comprising:

- at least one inductive device as defined above in the operational state, and
- a magnetic piece. The magnetic piece is disposed or formed in a casing of the inductive devices defined by openings of the inductive devices such that the inductive devices and the magnetic piece are inductively coupled.

[0011] In a third aspect of the invention, the applicant proposes a method of manufacturing an inductive assembly comprising:

- a) provide at least one printed circuit board having a plate shape and comprising main portions, the main portions having through openings,
- b) fold main portions relative to each other such that the printed circuit boards are rolled up around a molding core,
- c) mold a fluid magnetic material at least partially through the openings of the folded printed circuit boards.

[0012] Other features, details and advantages will be shown in the following detailed description and on the figures, on which:

- Figure 1 is a partial side view of a device according to the invention in a planar state;
- Figure 2 is a partial top view of the top-layer of the device of Figure 1;
- Figure 3 is a partial bottom view of the bottom-layer of the device of Figure 1;
- Figure 4 is a partial side view of the device of Figure 1 in an operational state;
- Figure 5 is a perspective view of a device according to the invention;
- Figure 6 is a side view of the device of Figure 5;
- Figure 7 is an enlarged view of a detail of Figure 6;
- Figure 8 is a top view of a device according to the invention in a planar state;
- Figure 9 is a view of a part of the device of Figure 8;
- Figure 10 is a view of a step of assembling of the part of Figure 9;
- Figure 11 is a top view of the top-layer of a device according to the invention;
- Figure 12 is a bottom view of the bottom-layer of the device of Figure 11;
- Figure 13 is a side view of the device of Figure 11 in an operational state;
- Figure 14 is a top view of the top-layer of a device according to the invention;
- Figure 15 is a bottom view of the bottom-layer of the device of Figure 14;
- Figure 16 is a side view of the device of Figure 14 in an operational state;

- Figure 17 is a schematic side view of a device according to the invention in an operational state;
- Figure 18 is a schematic side view of a device according to the invention in an operational state;
- Figure 19 is a schematic side view of a device according to the invention in an operational state; and
- Figure 20 is a schematic side view of a device according to the invention in an operational state.

[0013] Figures and the following detailed description contain, essentially, some exact elements. They can be used to enhance understanding the invention and, also, to define the invention if necessary. It should be understood that some details of the three dimension structure of the device are difficult to describe exhaustively other than by figures.

[0014] In the following, the word "annular" is used to geometrically define a form (3D) or a shape (2D) with a through opening (or a closed-loop, a close circle), whatever the outline forms. In other words, the word "annular" has not to be strictly interpreted as a circular/cylindrical meaning.

[0015] Figures 1, 2 and 3 show a part of an inductive device 1 in a planar state. The planar state of the inductive device 1 corresponds to an inactive state of the inductive device 1. The planar state can be considered as transitional state of the inductive device 1 during an assembling process of an inductive assembly including the inductive device 1. The inductive device 1 in the planar state has a general plate shape. In the planar state, the inductive device 1 has:

- a first direction, which can be seen as a longitudinal direction (x on the figures);
- a second direction, perpendicular to the first direction, which can be seen as a width direction (y on the figures);
- a third direction, perpendicular to the first and second directions, which can be seen as a thickness direction (z on the figures); and
- two opposite main faces substantially perpendicular to the third direction.

[0016] The inductive device 1 comprises a printed circuit board 2 (PCB). The PCB 2 includes at least a support layer 3 and at least one electrical conductive layer. In the examples, the PCB 2 comprises two electrical conductive layers: a top layer 4 and a bottom layer 6. The top layer 4 and the bottom layer 6 cover respectively each one of the main faces of the single support layer 3. In the context of a tridimensional structure described hereinafter, the words "top" and "bottom" are used to distinguish the two layers 4, 6 and according to figures 1, 2 and 3. In some situations, a part of the bottom layer 6 can be placed at a higher altitude than the top layer 4. In various embodiments, the PCB can comprise multilayers, including more than two electrical conductive layers.

[0017] The PCB 2 comprises a plurality of main por-

tions 11, 12. Here, the main portions 11, 12 are adjacent one to the other and aligned substantially along the first direction x. The main portions 11, 12 are delimited by folding lines 9, 9'. The folding lines 9, 9' extends in the second direction y perpendicular to the first direction x.

[0018] The main portions 11, 12 include N pairs $11_x, 12_x$ of adjacent portions ($11_A, 12_A, 11_B, 12_B, \dots, 11_N, 12_N$), wherein N is an integer. In the example of figures 1 to 4, $N = 1$. In the example of figures 5 to 7, $N = 7$. In the example of figure 8, $N = 3$. On figures, each pair is framed by a discontinuous line and referenced 8.

[0019] In the embodiment of the figures, each main portion 11, 12 has a substantially square outline, a square external rim. In various embodiments, the main portions 11, 12 can have other outline shapes, for example rectangular, circular or oblong. In the embodiments of the figures, each one of two opposite sides of the square shape corresponds to a folding line 9, 9'.

[0020] Each main portion 11, 12 has a through opening 13 forming a free path along the third direction z. In the embodiment of the figures, the openings 13 have a square outline, corresponding to a square internal rim of each main portion 11, 12. The openings 13 are substantially centered on each main portion 11, 12. In various embodiments, openings 13 can have another shape. The internal edge shape and the external edge shape of the main portions 11, 12 can be similar or different. The openings can be off-centered. Each main portion 11, 12 has an annular shape.

[0021] The two main portions $11_x, 12_x$ of each pair are planned to be folded substantially one on the other with respect to the common folding line 9 between them. The shape and size of the both main portions of each pair $11_x, 12_x$ is selected so that the two openings 13 are at least partially facing each other in said folded state to keep a free passageway in the folded state. In the embodiment of the figures, the two main portions of each pair $11_x, 12_x$ are shaped to match in the folded state.

[0022] Each folding line 9, 9' is physically obtained by forming a gap between the support layer 3 of a main portion 11; 12 and the support layer 3 of the adjacent main portion 12; 11. In other words, adjacent main portions 11, 12 are mechanically connected one to the other only by the electrical conductive layers 4 or 6. In such embodiments, the support layer 3 is made of a plurality of distant pieces and is discontinuous. In various embodiments, the folding lines 9, 9' can be obtained by forming grooves. The support layer 3 includes thin stripes between the main portions 11, 12. Such grooves can be obtained by machining, for example by shrinking material. In such embodiments, the support layer 3 is made in an integral piece, at least in the planar state of the inductive device 1.

[0023] In embodiments with a single conductive layer on a single face of the support layer, the PCB 2 is preferably arranged to be folded such that the conductive layer is on the inner face of the folding angle. The risk of deterioration of the conductive layer during folding oper-

ations is reduced. Thereby, the electrical continuity from one portion to another portion is preserved after folding operations. Preferably, there is a single continuous and conductive layer between two adjacent portions, through folding lines 9, 9'.

[0024] The PCB 2 comprises a track 15. The track 15 is electrically continuous and extends from an end portion to an opposite end portion of the main portions 11, 12 in the first direction x. The track 15 includes parts of electrical conductive layer(s) of the PCB 2, corresponding to the top layer 4 and the bottom layer 6 in the example of figures 1 to 4. The track 15 extends along the rims of the openings 13 on the first main face and/or the second main face of the PCB 2. An example of a track 15 is shown on figures 2 and 3. In the embodiments with a plurality of electrical conductive layers, the PCB 2 further comprises electrical connections between layers to ensure continuity of the track 15, for example vertical interconnect access 16 (VIA). In the example of figures 1 to 4, there is a single track 15. In various embodiments, the PCB 2 comprises a plurality of tracks 15 in order to obtain a multi-filar inductive device.

[0025] In the example of figures 1 to 4, each pair of two main portions 11, 12 includes substantially M loop(s), or turn(s), of the track 15, M being preferably an integer. For example, M is comprised between 1 and 20. In the embodiment of figures 1 to 4, the main portion 11 includes a half-loop on the top main face, included into the top layer 4 (figure 2), and one loop on the bottom face, included into the bottom layer 6 (figure 3), totaling 1.5 loop. The main portion 12 includes one loop on the top main face, included into the top layer 4 (figure 2), and a half-loop on the bottom face, included into the bottom layer 6 (figure 3), totaling 1.5 loop. In the folded state, the main portions 11, 12 of a pair form together an arm (see figure 4), the arm totaling, here, M=3 loops, or windings. In various embodiments, M is not an integer because the positions of the electrical connections of the track between two portions are not analogous in the PCB.

[0026] The layout of the track 15 is selected in order to form windings around the openings 13 when the inductive device 1 is in an operational state. The track 15 extends in a constant rotational direction around the openings 13. When the inductive device 1 is in an operational state and when a current circulates in the track 15, the induced magnetic fields of two coplanar loops of said track 15 are superimposed without being cancelling itself, such that the windings of the arm is electrically and magnetically efficient.

[0027] According to figures 1, 2 and 3, the portions of the track 15 between two adjacent portions 11, 12 of the PCB 2 can be the single mechanical link between said adjacent portions 11, 12. In such a case, the track 15, and especially the said portions, can be arranged in order to ensure mechanical link in function of the intended conditions of use. The track 15 is arranged to support at least one folding movement from the planar state to an operational state. The said portions of the track 15 can be

formed, for example, of a flexible wire or a flexible ribbon cable. Optionally, additional element can be added to reinforce the strength of the folding lines 9, 9'. The reinforcements can be structurally similar to portions of track 15.

[0028] In the example of figures 1 to 4, the PCB 2 further comprises secondary portions 17, 18. Here, each secondary portion 17, 18 has a shape and a size similar to the shape and size of a main portion 11, 12. The secondary portions 17, 18 are disposed respectively to an end and to an opposite end of the main portions 11, 12 in the first direction x. Each secondary portion 17, 18 is connected to a main portion 11, respectively to a main portion 12 by a folding line 9'. The track 15 extends in the first direction x beyond the main portions 11, 12, up to the secondary portions 17, 18.

[0029] In the example of figures 1 to 4, the PCB 2 further comprises base portions 30, 40. Here, the base portion 30, respectively the base portion 40, is adjacent to the secondary portion 17, respectively to the secondary portion 18. The base portion 30, respectively the base portion 40, is connected to the secondary portion 17, respectively to the secondary portion 18, by a folding line 9'. The base portions 30, 40 are disposed respectively to an end and to an opposite end of the other portions 11, 12, 17, 18 in the first direction x. Here, the track 15 extends in the first direction x beyond the secondary portions 17, 18 and up to the base portions 30, 40. The base portions 30, 40 are arranged to be fixed on a common support in a coplanar arrangement in the operational state (see figure 4) and to form claws of the inductive device 1.

[0030] In the example of figures 1 to 4, the track 15 forms a half loop on a single face of each secondary portion 17, 18. The track 15 on the secondary portions 17, 18 is only formed of the top layer 6 on the top main face of the PCB 2. The secondary portions 17, 18 are arranged to be put face to face in operational state (see figure 4) and to form a leg of the inductive device 1. Due to the openings 13 and the parts of the track 15 on the secondary portions 17, 18, such a leg forms a supplementary winding, with a single loop, in the embodiments of figures 1 to 4. Such features are optional. In various embodiments, such secondary portions 17, 18 can have only a structural function. For example, the secondary portions 17, 18 can have a shape and/or a size different from the main portions 11, 12. The openings can be absent. The layout of the track 15 can be different from a loop (or a half-loop). Electrical connections with other devices can be provided.

[0031] The secondary portions 17, 18 and/or the base portions 30, 40 can be used as a support and/or a connection for other electronical elements. In other words, the secondary portions 17, 18 and/or the base portions 30, 40 can be used as a classical PCB to plug electronical elements. Other electrical conductive tracks can be provided in function of the application, said tracks can be connected to the track 15.

[0032] In the operational state, corresponding to figure 4, the PCB 2 is folded such that each portion 11, 12, 17, 18 is rotated about folding lines 9, 9' with respect to the adjacent portions. The two main portions 11, 12 are superimposed one against the other by a complete folding.

[0033] The electrical isolation between the parts of the track 15 placed face to face is preserved. In the example of figures 1 to 4, it corresponds to the main faces visible on figure 3 of the main portions 11, 12. For example, an electrical insulating sheet is inserted between the two main portions 11, 12 or an insulating layer is preliminary deposited on the electrical layers 4, 6, or an air-gap is kept.

[0034] In the operational state, each main portion 11, 12 of each pair forms an angle α , β_1 , β_2 with an adjacent portion of the PCB 2 distinct from said pair. The angle α corresponds to an angle between two pairs 11, 12 (see figure 6). The angles β_1 , β_2 correspond to angles between a pair 11, 12 and another part of the PCB 2 (see figures 4 and 6). In the example of figures 1 to 4, there is a single pair of main portions 11, 12 ($N = 1$). Thus, the adjacent portions distinct from said pair corresponds to the secondary portions 17, 18. The said angles α , β_1 , β_2 are strictly greater than zero. In other words, the folding is partial between pairs. The arm formed by the main portions 11, 12 is not superimposed with the leg formed by the secondary portions 17, 18.

[0035] In the operational state, the openings 13 define together a casing 20 able to accommodate a magnetic piece to be inductively coupled to windings formed by the track 15.

[0036] The embodiments with a single pair of main portions 11, 12 is a specific case which is sufficient to obtain an inductive coupling with a magnetic piece. For example, two inductive devices 1, each one with a single pair of main portions 11, 12, can be combined with a common magnetic piece. Such an assembly would form an electrical transformer.

[0037] The embodiment of figures 5 to 7 will be now described by comparison with respect to the embodiment of figures 1 to 4. The identical numerical references used in the two embodiments refer to similar objects. On figure 5, the electrical conductive layers 4, 6 are shown but the layout of the track 15 is not represented. The layout of the track 15 can be, for example, similar to the layout described above with respect to figures 2 and 3.

[0038] The embodiment of figures 5 to 7 pertains to embodiments with at least two pairs of main portions 11_x , 12_x , where $x \in [1; N]$ and $N \geq 2$. Here, there are 7 pairs of main portions 11, 12 ($N = 7$). Said pairs 11_x , 12_x are similar one to another. In the operational state (see figure 5 and 6), the inductive device 1 has substantially a symmetry of revolution: geometrically, each arm formed by a pair of main portions (11_x , 12_x) results from a rotation of another pair of main portions (11_y , 12_y) with respect to an axis YY parallel to the second direction y. As a consequence, the general tridimensional form of the inductive device 1 in the operational state as it is shown

on figures 5 and 6 looks like a flower.

[0039] In various embodiments, N can be different from 7. The sizes of the main portions (11_x ; 12_x) of each pairs (11_x , 12_x) can be different from each other (11_y , 12_y). For example, the size of the pairs can be mutually adapted such that the inductive device in the operational state has a form which is not a symmetry of revolution. The general tridimensional form of the inductive device 1 can be elongated, for example, parallelepiped or oblong.

[0040] In the embodiment of figures 5 to 7, the PCB 2 is equivalent to the PCB 2 of figure 4 wherein each pair 11_x , 12_x forms a pattern corresponding to the frame 8 on figures 1 to 4. In the inactive state of the embodiment, the pattern is N-replicated along the first direction x, optionally with differences of the layout of the track 1 between the pairs 8. The N pairs 11_x , 12_x are juxtaposed along the first direction x. The two main portions 11_x , 12_x of a common pair are delimited by a folding line 9 (like on figures 2 and 3). The two main portions 12_x , 11_y of respective adjacent pairs 11_x , 12_x and 11_y , 12_y are delimited by a folding line 9'.

[0041] When the PCB 2 is folded from the inactive and planar state to the operational and tridimensional state, the direction of the rotation is alternated from one folding line 9 to the adjacent folding line 9' along the first direction x. In other words, the main portions 11, 12 and the secondary portions 17, 18 are folded in manner of an accordion. The PCB 2 is folded such that each portion 11, 12, 17, 18 is rotated about folding lines 9, 9' with respect to the adjacent portions. The two main portions 11_x , 12_x of each pair are superimposed one against the other by a complete folding. The electrical isolation between the parts of the track 15 placed face to face is preserved.

[0042] In the operational state, each main portion 11_x , 12_x of each pair forms:

- an angle α with an adjacent main portion 12_y , 11_x of an adjacent pair, α being not necessarily constant between each pair of an inductive device 1, and/or
- an angle β_1 or β_2 with an adjacent secondary portion 17, 18 of the PCB 2.

[0043] The said angles α and β_1 , β_2 are strictly greater than zero. In other words, the folding is partial, resulting from a rotation of strictly less than 180° , such that the arms formed by each pair of main portions 11_x , 12_x are not superimposed with the other arms or with the leg formed by the secondary portions 17, 18. In the example of figures 5 to 7, the said angles α and β_1 are equals to each other and substantially equal to $360^\circ / (N+1) = 45^\circ$. In various embodiments, the angles can be different one from the others.

[0044] In the operational state, the openings 13 define together a casing 20 able to accommodate a magnetic piece to be inductively coupled to windings formed by the track 15. In the example of figures 5 to 7, the casing 20 has an annular form. For example, a magnetic piece can have a toroidal form. The toroidal form can have a

circular or a non-circular section (for example a square section). The magnetic piece is composed at least partly of a material having ferromagnetic properties, for example iron powder or ferrite.

[0045] In the operational state of the embodiment of figures 5 to 7, due to the thickness of each arm, a free space 21 is formed in a central part of the inductive device 1 (centered on the axis YY). Such a free space 21 and the space between the arms can be used to enhance the cooling of the inductive device 1 during operation.

[0046] Figure 7 shows an arm of a pair of main portions 11_x, 12_x. The superimposition of four electrical conductive layers 4, 6 connected by VIA 16 and forming a part of the track 15 can be viewed.

[0047] The PCB 2 can be manufactured in the inactive and planar state, at least partly by known technics. The support layer 3 is preferably rigid. The word rigid is defined in the meaning that the support layer 3 can be broken rather than to be bent. For example, the support layer 3 can be made of glass-reinforced epoxy. The rigidity of the support layer 3 enhances the good mechanical strength of the tridimensional structure. As explained above, the support layer 3 can be made of portions delimited by thin lines forming the folding lines 9, 9'. As long as the electrical continuity of the track 15 from one portion to another portion is preserved, two adjacent portions can be at least partially broken along their common folding line 9, 9' during a mounting of the inductive device 1.

[0048] The electrical conductive layers 4, 6 and the layout of the track 15 can be made by known methods, for example by selective chemical copper etching or by electroplating. Preferably, the thickness of the track is superior or equal to 105 micrometers.

[0049] In some embodiments, the track 15 of the PCB 2 can also comprise a wire or a plurality of wires embedded in the support layer 3. For example, WO 2006/077163, WO 2006/077164 and WO 2006/077167 describe methods to form tracks in or on a PCB that are planned to support power level of electricity.

[0050] Figure 8 shows an embodiment of an inductive device 1. A general structure of the PCB 2 is shown in the inactive and planar state view from the top. Only the general forms and mutual arrangement of the parts of the PCB are shown, without details like the openings 13 or the track 15.

[0051] In the center of figure 8, the PCB 2 comprises three pairs (N = 3) of main portions 11, 12, two secondary portions 17, 18 and two base portions 30, 40 which are similar to the embodiments previously described. The PCB 2 further comprises housing portions 31, 32, 33, 34, 41, 42, 43, 44. The housing portions 31, 32, 33, 34, are arranged to form a part of a container in combination with the base portion 30 in the operational state. The housing portions 41, 42, 43, 44, are arranged to form a part of a container in combination with the base portion 40 in the operational state. The two parts of a container are mutually arranged to form together a container, or housing, in the operational state. Such a container can contain the

other parts of the inductive device 1, including the arms and the magnetic piece. The base portion 30 and the housing portions 31, 32, 33, 34 are mutually connected by folding lines 9', 9". The base portion 40 and the housing portions 41, 42, 43, 44 are mutually connected by folding lines 9', 9".

[0052] In the embodiment of figure 8, when the inductive device 1 is in its operational state, the container has substantially a parallelepiped form. The base portions 30, 40 are coplanar and, here, perpendicular to the third direction z. The portions 31 and 32 are placed face to face and perpendicular to the second direction y. The portions 41 and 42 are placed face to face and perpendicular to the second direction y. The portions 31 and 42 are coplanar. The portions 41 and 32 are coplanar. The portions 33 and 43 are placed face to face and perpendicular to the first direction x. The portion 34 and 44 are coplanar and placed facing to respectively the base portion 30 and the base portion 40, and perpendicular to the third direction z.

[0053] Contrary to what one might think *a priori*, to enclose the active parts of the inductive device 1 enhances the thermal dissipation, the cooling. It seems that the thermal conductivity of the PCB 2 facilitates the thermal dissipation. The heat can be evacuated from critical parts, especially from the arms formed by the main portions 11, 12 toward the base portions 30, 40 and the housing portions 31, 32, 33, 34, 41, 42, 43, 44. In an operational state, the housing can, for example, receive a thermal conductive material in contact with the magnetic piece. A fluidic or pasty thermal conductive material can be kept in contact with hot parts by the base portions 30, 40 and the housing portions 31, 32, 33, 34, 41, 42, 43, 44. In another operational state, the magnetic material is formed in the housing produced by portions 31, 32, 33, 34, 41, 42, 43, 44, thus the magnetic material is conformal with the housing and the thermal interface between the magnetic piece and the housing is improved.

[0054] Figures 9 and 10 show in details an example of the base portion 30 and the housing portions 31 and 32. The neighboring portions exist but are not represented on the figures 9 and 10.

[0055] The base portion 30 and the housing portions 31 and 32 contain a high portion of thermally conductive material. In the example, the portions of the PCB 2 support metallic tracks 50 (here in copper). A main function of the tracks 50 is, in the context, to enhance the conduction of the heat along the PCB portions. In the example, the tracks 50 are not used to voluntarily carry electricity. The tracks 50 can also have a magnetic shield function, for example to limit the magnetic dispersion. The number, the layout and generally the tracks 50 as shown on figure 9 are only examples. The tracks 50 can have different locations, structures or forms in function of the forms of the inductive device 1 and the intended application.

[0056] The housing portion 31 supports a thermal conductive member 51. Here, the thermal conductive mem-

ber 51 is formed of a bar made of a thermal conductive material, for example copper or aluminum. The form, the size and the location of the thermal conductive member 51 on the housing portion 31 are especially arranged in order to be disposed in a central opening of an annular magnetic piece. The central opening, in the embodiments described above corresponds to the free space 21 (see figure 5). In the operational state, the conductive member 51 forms a thermal drain, which evacuates the heat from the arms toward the housing portion 31. The conductive member 51 also forms a spacer to dispose the pairs 11, 12 easily with respect to the others when the PCB 2 is built from a planar state to an operational state. The conductive member 51 could also forms a part of the mold or a molding core to create the magnetic piece inside the PCB 2 as it will be described hereinafter.

[0057] The tracks 50 and the thermal conductive member 51 are optional and can be used independently. The combination of the tracks 50 and the thermal conductive member 51 is particularly efficient to evacuate the heat from the inductive device 1.

[0058] A through hole 52 is formed into the base portion 30. As shown on figure 10, the hole 52 is used to fix the base portion 30, and consequently the inductive device 1, to a support 100. In the example, a couple screw-nut is used. For example, the nuts is glued to the base portion 30 or directly molded into the magnetic paste described hereinafter. Other fastening means can be used. The base portion 30 also support a thermal conductive part 53 fixed on the external main face of the base portion 30. The "external main face" means outside from the housing in the operational state (see the arrows representing the folding movements of the housing portions 31, 32 on figure 10). The thermal conductive part 53 is disposed substantially around the hole 52 such that to be maintained in tight contact between the inductive device 1 and the support 100 and to evacuate the heat from the inductive device 1 toward the support 100. The thermal conductive part 53 has a mechanical function: it strengthens the base portion 30 and provides a planar and rigid surface. The thermal conductive part 53 has also a thermal function: it enhances the spreading of the heat so that it is more efficiently transferred to the support 100. For example, the thermal conductive part 53 is attached to the base portion 30 by a lamination process.

[0059] The thermal conductive part 53 can be a metal plate, for example made of copper or aluminum. Such a metal plate can be fixed to the PCB by a thermal conductive pre-preg. Such a combination has preferably a high thermal conductivity and a low electrical conductivity, preferably a thermal conductivity superior to $3 \text{ W.m}^{-1}.\text{K}^{-1}$ and a breakdown voltage superior to 2 kV. The support 100 itself can be a heat sink. Thermal grease can also be added to enhance the thermal conductivity between elements. In the embodiments comprising a combination of thermal conductive elements, the heat can be evacuated from the active parts of the inductive device 1 toward outside, for example toward the support

100 and/or a heat sink.

[0060] In the examples of figure 9 and 10, only portions 30, 31, 32 comprise tracks 50, a thermal conductive member 51, a hole 52 and a thermal conductive part 53. In various embodiments, one of the elements or a combination thereof can be adapted to other parts of the inductive device 1, especially to similar portions 40, 41, 42.

[0061] When the embodiment of figure 8 is combined with other electrical components, the applicant noted that the heat dissipation is particularly efficient for the inductive element itself and also for said electrical components such as capacitors and semi-conductors.

[0062] The inductive device 1 can be used for example to form a transformer or an inductor. The inductive device 1 can be combined with other elements to form an assembly. An inductive assembly can comprise an inductive device 1 in the operational state, and a magnetic piece disposed in the casing 20 of the inductive device 1. The inductive device 1 and the magnetic piece can be inductively coupled. The air enables to convey magnetic field. The inductive device 1 can be deprived from any magnetic piece and operate with air. The inductive device 1 and the magnetic piece can be provided separately or into a kit. Such a kit can comprise other article, for example electronic component, to be assembled. Before to be used, the inductive device 1 can be kept in a planar state, for example during manufacturing, storage and/or transport.

[0063] Figures 11, 12 and 13, and figures 14, 15 and 16 show two embodiments of the PCB 2. The numerical references identical to that of previous figures correspond to analogous elements. The operational states are similar to the operational state of the embodiment of figures 1 to 4. The planar states are different.

[0064] In the embodiment of figures 11, 12 and 13, the PCB 2 includes an odd number of pair(s) of main portions 11, 12 (here, $N=1$). The portions 11, 12, 17, 18, 30 and 40 of the PCB 2 are not aligned in a common direction. The base portion 30, the secondary portion 17 and the main portion 11 are aligned in the first direction x. The base portion 40, the secondary portion 18 and the main portion 12 are also aligned in the first direction x. The base portion 40, the secondary portion 18 and the main portion 12 are disposed parallel to the base portion 30, the secondary portion 17 and the main portion 11. The main portions 11, 12 are aligned substantially along the second direction y in the inactive state of the PCB 2. The folding line 9 between the main portions 11, 12 is oriented into the first direction x perpendicular to the second direction y.

[0065] In the example, the secondary portion 18 and the base portion 40 are on the same side as the secondary portion 17 and the base portion 30 with respect to the pair of main portions 11, 12 (on the left side on figure 11). The secondary portions 17, 18 are aligned along the second direction y and the base portions 30, 40 are aligned along the second direction y. The PCB 2 further comprises a cutting line 10, extending in the first direction

x, in the extension of the folding line 9 of the pair 11, 12, between the base portion 30 and the base portion 40, and between the secondary portion 17 and the secondary portion 18. In various embodiments, the secondary portion 18 and the base portion 40, and the secondary portion 17 and the base portion 30 can be on the opposite side with respect to the pair of main portions 11, 12. In such a case, a cutting line 10 is useless.

[0066] The cutting line 10 is, in the example, a weakened part of the PCB 2, arranged to be voluntarily broken and to separate the base portions 30, 40 from each other and to separate the secondary portions 17, 18 from each other when the PCB 2 is built in the operational state. In various embodiments, the cutting line 10 can be an air gap in the planar state, avoiding a breaking action during the building of the inductive device 1.

[0067] Like in the previous embodiments, the track 15 extends continuously and successively from the base portion 30 to the base portion 40 passing by the secondary portion 17, the main portion 11, the main portion 12 and the secondary portion 18. The layout of the track 15 is different from the layout of the previous embodiments. The main portion 11 includes three quarters of a loop on the top main face, included into the top layer 4 (figure 11), rather than a half-loop (figure 2). The main portion 12 includes three quarters of a loop on the top main face, included into the top layer 4 (figure 11), rather than an almost entire loop (figure 2). In the folded state, the main portions 11, 12 of the pair form together an arm (see figure 13), the arm totaling $M=3$ loops, or windings, like in the previous embodiments.

[0068] In the embodiment of figures 14, 15 and 16, the PCB 2 includes an even number of pairs of main portions 11, 12 (here, $N=2$). The two pairs are referenced 11_1 ; 12_1 , and 11_N ; 12_N respectively.

[0069] The main portions 11_1 , 12_1 are aligned substantially along the second direction y in the inactive state of the PCB 2. The main portions 11_N , 12_N are aligned substantially along the second direction y in the inactive state of the PCB 2. Each folding line 9 between the main portions 11_1 , 12_1 , respectively between the main portions 11_N , 12_N , is oriented into the first direction x perpendicular to the second direction y. The other folding lines 9, 9' are oriented into the second direction y.

[0070] The second pair of main portions 11_N , 12_N are on the same side as the secondary portion 17 and the base portion 30 with respect to the first pair of main portions 11_1 , 12_1 (on the left side on figure 11). The secondary portion 17 and the second pair of main portions 11_N , 12_N are aligned along the second direction y. The first pair of main portions 11_1 , 12_1 are on the same side as the secondary portion 18 and the base portion 40 with respect to the second pair of main portions 11_N , 12_N (on the right side on figure 11). The secondary portion 18 and the first pair of main portions 11_1 , 12_1 are aligned along the second direction y. The PCB 2 comprises two cutting lines 10, extending in the first direction x, each in the extension of one of the folding lines 9 of the pairs

11_1 , 12_1 , 11_N , 12_N , between the secondary portion 17 and the main portion 11_N , and respectively between the secondary portion 18 and the main portion 12_1 . The cutting lines 10 are similar to the cutting line of figures 11, 12.

[0071] The layout of the track 15 is also slightly different from the layout of the previous embodiments. A man skilled in the art would understand that the layout of the track 15 can be arranged in function of the mutual arrangement of the portions of the PCB. In various embodiments, the number of pairs can be different, for example by increasing the number of pairs with respect to the example of figures 11, 12 and 13 (where N is an odd number) and/or the example of figures 14, 15 and 16 (where N is an even number).

[0072] In the embodiments of figures 11 to 16, the PCB 2 is equivalent to the PCB 2 of figure 4 wherein each pair 11_x ; 12_x is referenced 8. The pairs 8 can be N-replicated with differences of the layout of the track 15.

[0073] Figure 17 shows schematically a various operational state of a PCB 2. By comparison with respect to the form of figures 5 and 6, the PCB 2 further comprises intermediate portions 60. In such an embodiment, the two main portions 11_x , 12_x of each pair 8 are connected one to the other by an intermediate portion 60. An intermediate portion 60 is connected respectively to each one of the main portions 11_x , 12_x of the pair by a respective folding line 9, 9' such that to have an angle between said two main portions 11_x , 12_x in the operational state of the PCB 2. Each intermediate portion 60 further comprises a part of the track 15 such that to ensure electrical continuity of the track 15 from one to the other main portion 11_x , 12_x . In the operational state of such an embodiment, the main portions 11_x , 12_x of a pair are not superimposed.

[0074] Figure 18 shows schematically a various operational state of a PCB 2. By comparison with respect to the form of figures 5 and 6, the sizes of the main portions of two distinct pairs are different. On figure 18, the main portions of the vertical and horizontal pairs are shorter than the main portions of diagonal pairs. This enables to adapt the general form of the inductive device 1 in the operational state of the PCB 2. Figure 18 shows an example of a device 1 having a parallelepiped form. The form and size of the openings 13 can also be adapted in order to adapt the form of the casing 20.

[0075] The embodiments of the inductive device 1 described until now are made of a single PCB 2 with a single track 15. The inductive devices 1 are inductors. In various embodiments, for example on figures 19 and 20, the inductive device 1 comprises more than one PCB 2, for example two PCB 2. Each one of the two PCB 2 comprises a single track 15 electrically isolated one from the other in the operational state. The two PCB 2 are arranged in order to form, in the operational state, a common casing 20. Each one of the two PCB 2 forms respectively a primary winding and a secondary winding. Together, the two PCB 2 form the inductive device 1, which can be, here, a transformer.

[0076] In various embodiments, the single PCB 2, or at least one among a plurality of PCB 2, can comprise:

- at least one split track, and/or
- a plurality of independent tracks.

[0077] A split track is a track for which the two ends of the track are neighboring, for example on the same portion of the PCB 2. The track comprises two successive parts, the first part passing by each portion of the PCB 2 on a first side of each opening 13, the second part passing by each portion of the PCB 2 on the opposite side of each opening 13, the two parts being connected one to the other by an U-turn around an opening 13 of a portion of the PCB 2. For example, a track can start (having a first end connection) on the base portion 30 of the PCB 2 of figures 5 and 6, to extend from the base portion 30 to the base portion 40 (the first part of the track), to make a U-turn on the base portion 40, to extend from the base portion 40 to the base portion 30 (the second part of the track), and ends (having a second end connection) on the base portion 30. The layout of the track is arranged to form windings around the openings 13 in the operational state of the PCB 2. Such a split track can be provided, for example, on each one of the PCB embodiments shown on figures 1 to 20.

[0078] In a planar state, a plurality of independent tracks on the same PCB can have a similar layout, for example being substantially parallel along their path. In an operational state, the ends of each track can be connected two by two such as to be electrically equivalent to a single continuous track.

[0079] In an operational state, the two ends of each track can be connected to a respective circuitry. Thus, the tracks are electrically isolated and inductively coupled by the magnetic piece. For example, two tracks electrically independent and substantially parallel along their path can form a primary and a secondary winding on the same PCB. Such a single PCB forms a transformer.

[0080] The known inductive devices, especially thus designed to at least kilowatt levels (current of several amperes) have a large magnetic section, a large volume, a large mass and are also difficult to cool down. The known inductive devices are generally made by assembling a plurality of discrete pieces. Due to the limited number of models for each discrete piece and their availability at each time, each industrial actor has usually to make a compromise between the best technical features (theoretic) in function of each application, and the cost of the unitary pieces (economical reality). The adaptability of the inductive devices is very limited. According to the inductive device 1 with a foldable PCB, the specific features of each inductive device can be easily and precisely selected in function of each application. It will be understood that the precise features are almost unlimited (especially number, sizes and shapes of main sections 11, 12 ; number of loops by arm, section and layout of the track, form and size of the magnetic piece, external

form and size of the optional housing, configuration of the various cooling options).

[0081] In addition, the manufacturing of such an inductive device 1, or the manufacturing of an assembly including the inductive device 1, can be highly or totally automated. This enables to reduce the manufacturing cost.

[0082] An assembly comprising the inductive device 1 can be manufactured by a process as follows:

- a) provide a PCB 2 having a plate shape and comprising the main portions 11, 12 with through openings 13,
- b) fold the main portions 11, 12 relative to each other such that the PCB 2 is rolled up around a molding core, for example the thermal conductive member 51,
- c) mold a fluid magnetic material at least partially through the openings 13 of the folded PCB 2.

[0083] The step a can comprise to form the folding lines 9, 9' as explained above.

[0084] The step b can comprise to dispose a spacer or a set of spacers in order to temporarily maintain the folded PCB 2 in its final position during the molding. Referring to the embodiment of figures 5 and 6, the PCB 2 can be maintained in its "flower" form for example.

[0085] The step c can comprise to fix a mold or a set of mold parts with respect to the folded PCB 2. The housing portions described before can also be used to form a mold. The fluid magnetic material can comprise, for example, a powder or a combination of powder with resin and/or glue. In function of the magnetic material, the step c can also comprise a curing, preferably at a temperature less than 200°C.

[0086] The assembling process can further comprise to remove the molding core from a center of the solid magnetic piece after molding.

[0087] The features of the embodiments of inductive devices described here can be combined with each other. An advantage of such an inductive device is the high adaptability: the forms and sizes of the inductive device, in the planar state and in the operational state, can be arranged in function of the needs and the final use. A man skilled in the art would easily understand that other embodiments of inductive devices according to the invention can have forms and sizes very different from thus shown on figures while providing similar electromagnetic functions.

[0088] The invention is not limited to the devices, assemblies, kits and process described here, which are only examples. The invention encompasses every alternative that a person skilled in the art would envisage in the scope of the following claims.

Claims

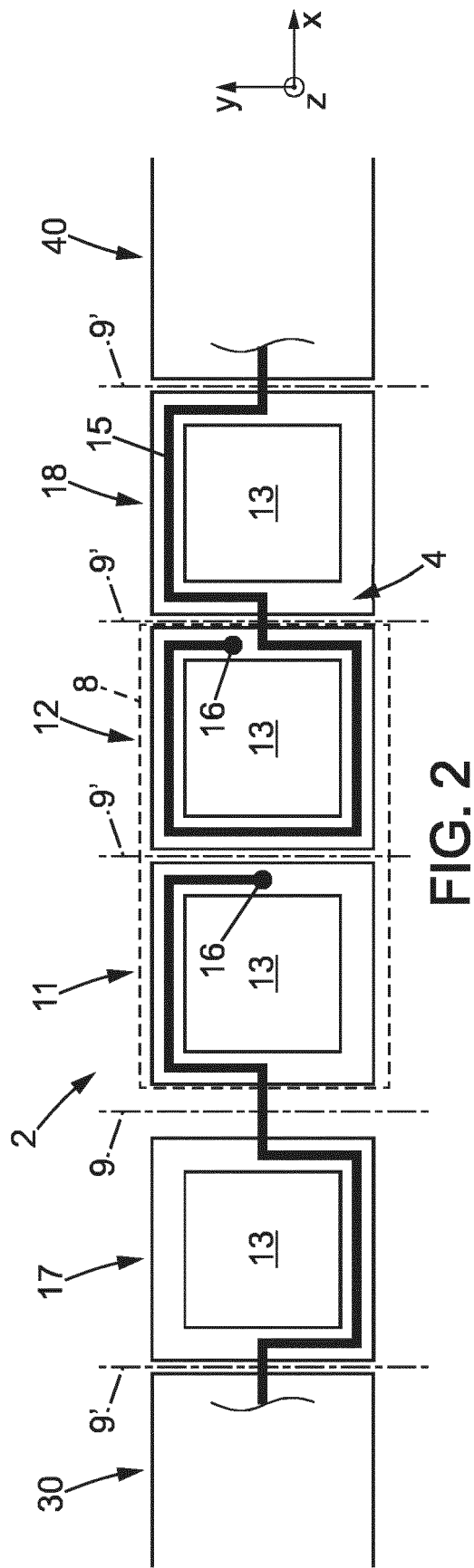
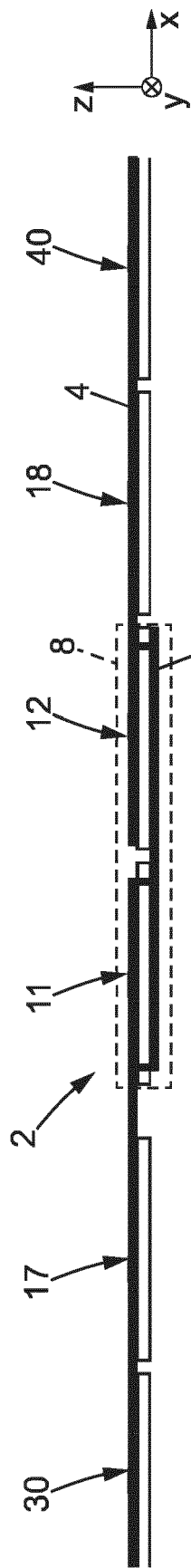
1. Inductive device (1) comprising at least one printed circuit board (2), the printed circuit board (2) comprising N pairs of main portions (11, 12), wherein N is an integer superior or equal to 1, each main portion (11, 12) being connected to the other portions (11, 12, 17, 18, 60) by folding lines (9, 9'), each main portion (11, 12) having a through opening (13) forming a path in a thickness direction (z) of said main portion (11, 12),
the printed circuit board (2) comprising at least one track (15) electrically continuous and extending along the rims of the openings (13) and passing by each one of the main portions (11₁, 12₁, 11_N, 12_N), the printed circuit board (2) having an inactive state wherein the printed circuit board (2) has a plate shape, and an operational state wherein:
 - the printed circuit board (2) is folded such that each main portion (11, 12) is rotated about folding lines (9, 9') with respect to the adjacent portions (11, 12, 17, 18, 60),
 - each main portion (11_x, 12_x) of each pair forming an angle (α , β_1 , β_2) with an adjacent portion (11_y, 12_y, 17, 18) of the printed circuit board (2) distinct from said pair, the angle (α , β_1 , β_2) being strictly greater than zero, and
 - the openings (13) defining together a casing (20) able to accommodate a magnetic piece to be inductively coupled to windings formed by the track (15).
2. Inductive device (1) according to claim 1, wherein the track (15) extends on at least two distinct layers (4, 6) of the printed circuit board (2), the printed circuit board (2) comprising Vertical Interconnect Access (16) interconnecting parts of the track (15) between the at least two distinct layers (4, 6).
3. Inductive device (1) according to one of the preceding claims, wherein the two main portions (11_x, 12_x) of each pair are adjacent one to the other and connected one to the other by a folding line (9, 9'), the two main portions (11_x, 12_x) of each pair being superimposed one against the other by a complete folding about said folding line (9, 9') in the operational state.
4. Inductive device (1) according to one of claims 1 and 2, wherein the two main portions (11_x, 12_x) of each pair are connected one to the other by an intermediate portion (60), said intermediate portion (60) being connected respectively to each one of the main portions (11_x, 12_x) of said pair by a respective folding line (9, 9') such that to have an angle between said two main portions (11_x, 12_x) in the operational state of the printed circuit board (2), said intermediate portion (60) further comprising a part of the track (15) such that to ensure continuity of said track (15) from one to the other said main portions (11_x, 12_x) of said pair.
5. Inductive device (1) according to one of the preceding claims, wherein the main portions (11, 12) are aligned substantially along a first direction (x) in the inactive state of the printed circuit board (2) such that said folding line (9, 9') are oriented into a second direction (y) perpendicular to the first direction (x).
6. Inductive device (1) according to one of the preceding claims, wherein each pair of main portions (11_x, 12_x) comprises M turns of the track (15) around the openings (13), where M is comprised between 1 and 20.
7. Inductive device (1) according to one of the preceding claims, wherein the track (15) comprises a wire embedded inside the printed circuit board (2).
8. Inductive device (1) according to one of the preceding claims, including N pairs of main portions (11_x, 12_x), wherein N is superior or equal to 2.
9. Inductive device (1) according to claim 8, wherein the pairs are similar one to another such that each pair forms a pattern (8) and the pattern (8) is N-replicated.
10. Inductive device (1) according to one of the claims 1 to 8, wherein the sizes of the main portions (11_x; 12_x) of each pair (11_x, 12_x) are different from other pair (11_y, 12_y) and mutually adapted such that the device (1) has a substantially elongated tridimensional form in the operational state.
11. Inductive device (1) according to one of the preceding claims, wherein the printed circuit board (2) further comprises portions (17, 18, 30, 40) arranged to form legs and/or claws in the operational state to fix the device (1) to other components.
12. Inductive device (1) according to claim 11, wherein at least one of said portions (17, 18) arranged to form legs and/or claws has a through opening (13) and a part of the track (15) extending along the rims of said opening (13), such that said opening (13) defines in part the casing (20) and said part of the track (15) forms at least partially a loop around said casing (20).
13. Inductive device (1) according to one of the preceding claims, wherein the printed circuit board (2) further comprises portions (30, 31, 32, 33, 34, 40, 41, 42, 43, 44) arranged to conjointly form a housing in the operational state to receive a thermal conductive material and/or the magnetic piece.

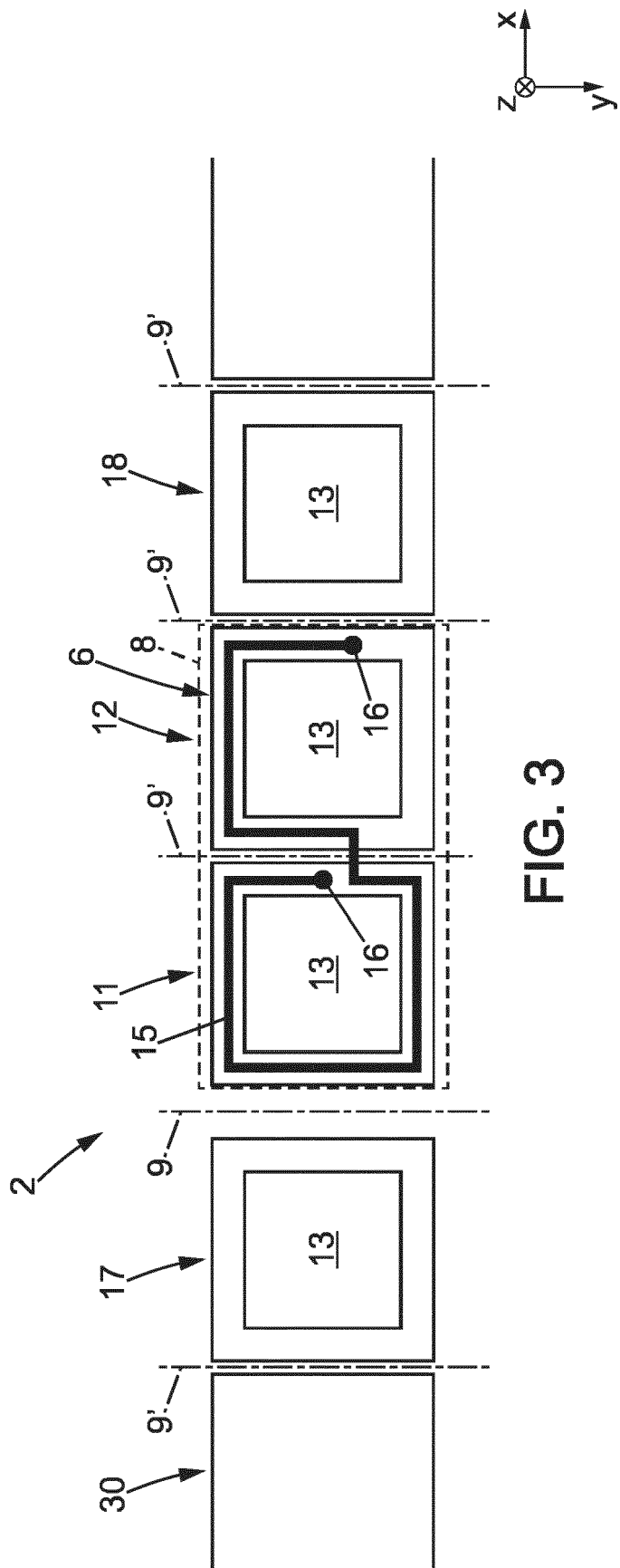
14. Inductive device (1) according to one of the preceding claims, wherein the printed circuit board (2) further comprises a thermal conductive member (51) arranged to be disposed in a central opening (21) of an annular magnetic piece. 5
15. Inductive device (1) according to one of the preceding claims, wherein the printed circuit board (2) further comprises portions (30, 31, 32) including a combination of metallic tracks (50) able to conduct heat toward a predefined area arranged to be in contact with a heat sink. 10
16. Inductive assembly comprising: 15
- at least one inductive device (1) according to one of the preceding claims in the operational state, and
 - a magnetic piece, 20
- the magnetic piece being disposed or formed in a casing (20) of the inductive devices (1) defined by openings (13) of the inductive devices (1) such that the inductive devices (1) and the magnetic piece are inductively coupled. 25
17. Method of manufacturing an inductive assembly comprising: 30
- a) provide at least one printed circuit board (2) having a plate shape and comprising main portions (11, 12), the main portions (11, 12) having through openings (13), 30
 - b) fold main portions (11, 12) relative to each other such that the printed circuit boards (2) are rolled up around a molding core, 35
 - c) mold a fluid magnetic material at least partially through the openings (13) of the folded printed circuit boards (2). 40

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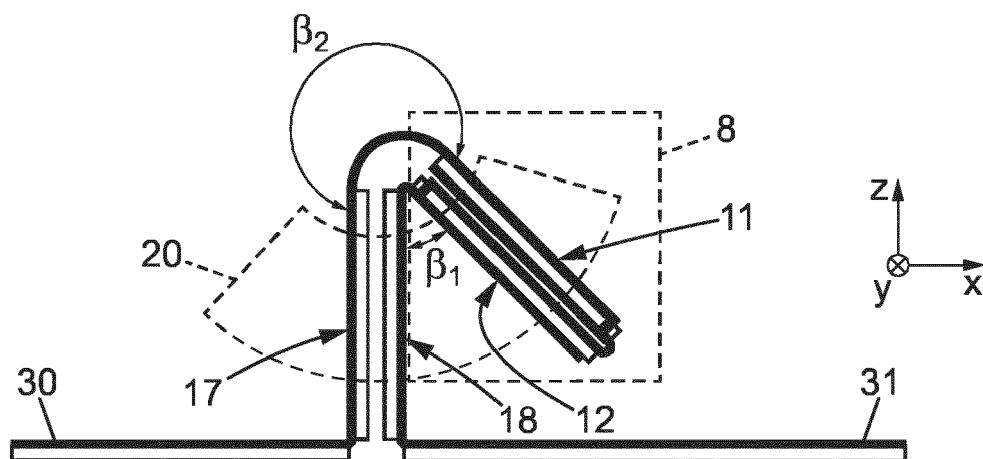


FIG. 4

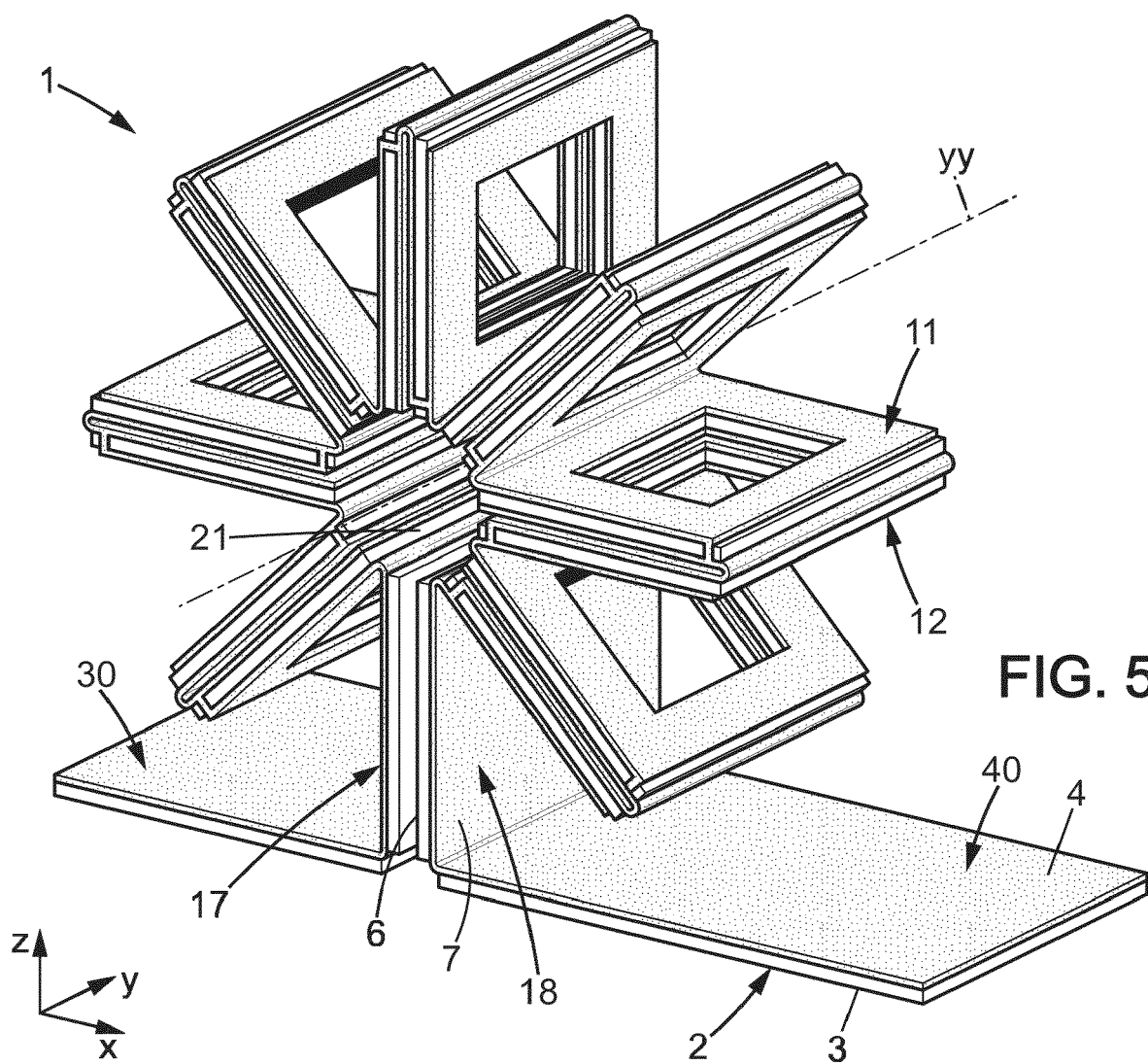
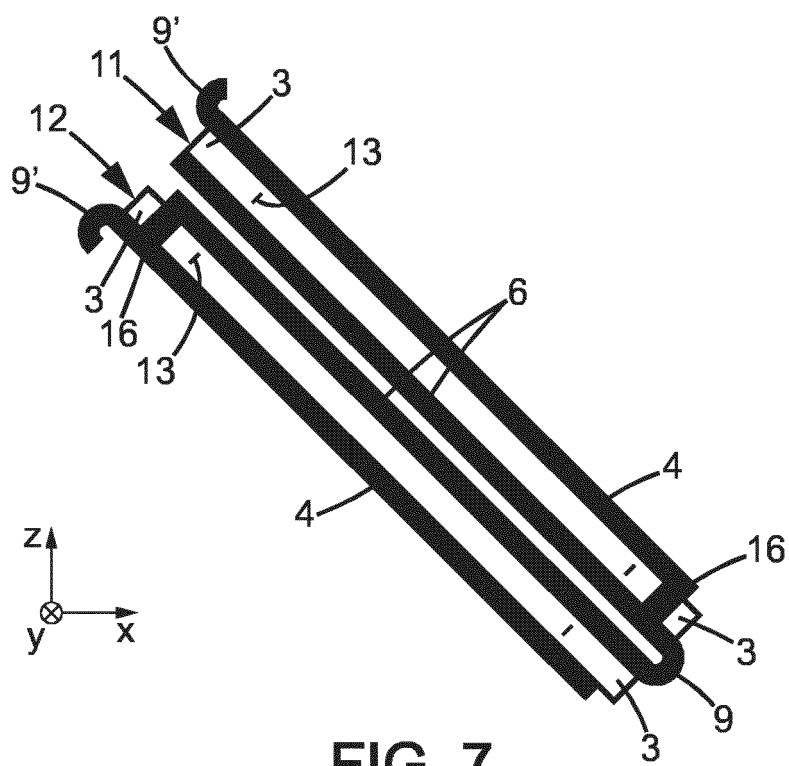
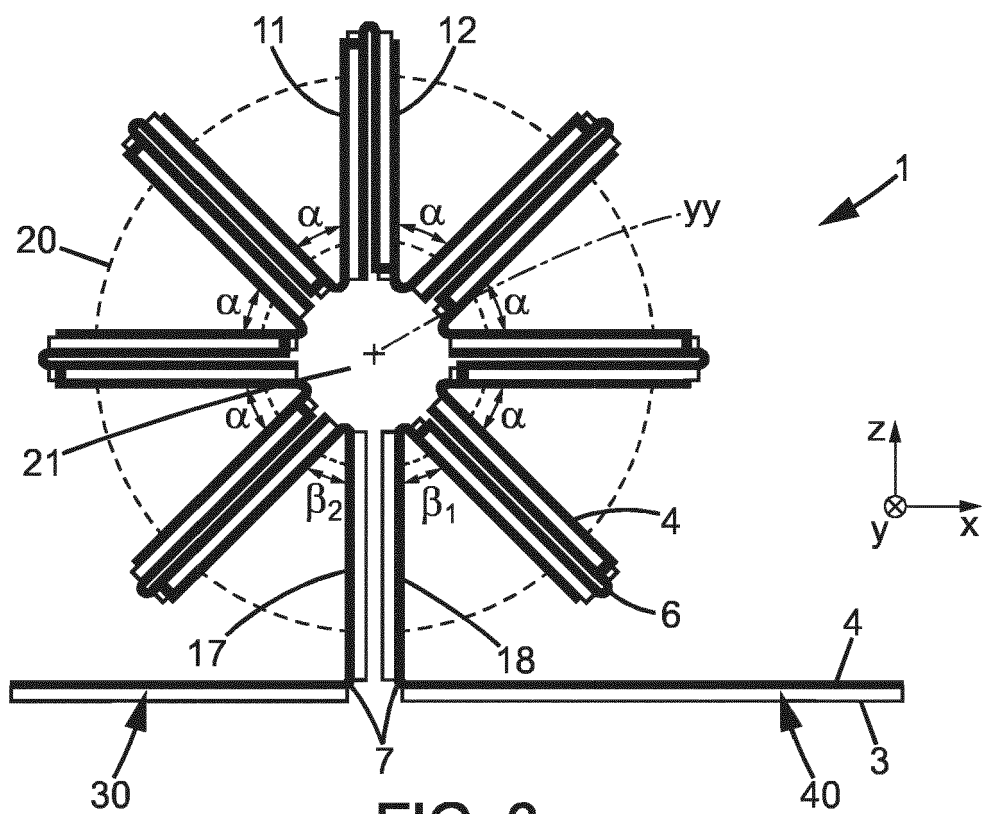
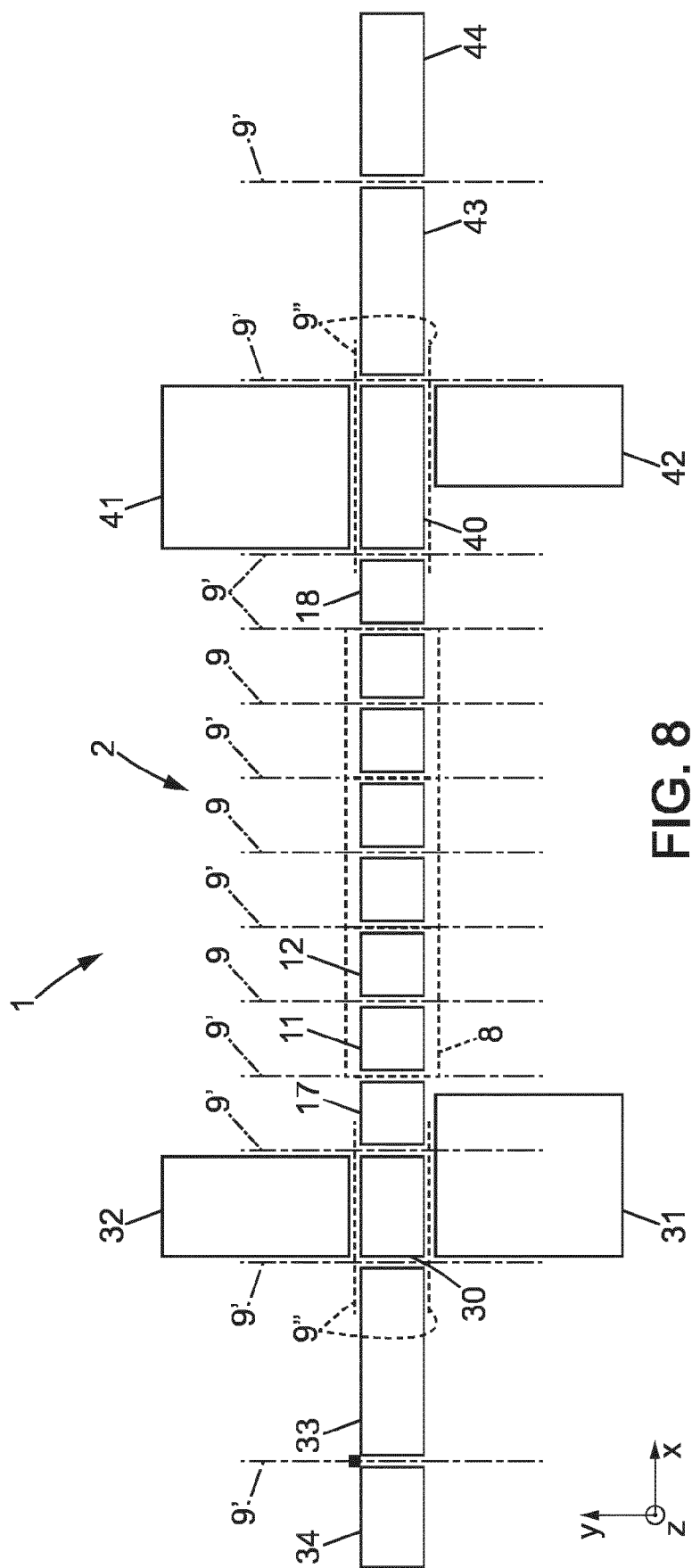


FIG. 5





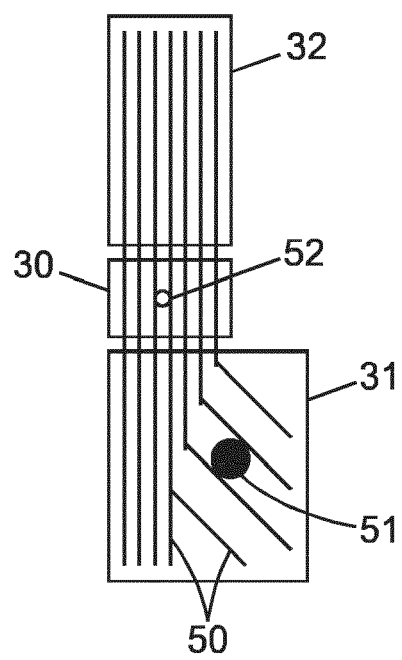


FIG. 9

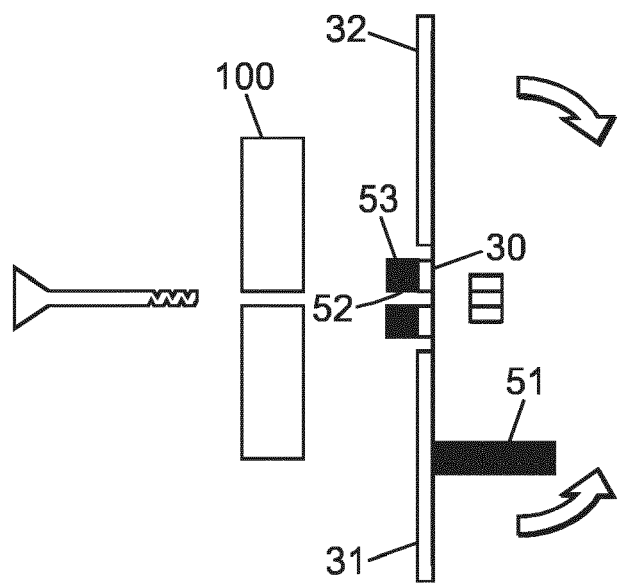


FIG. 10

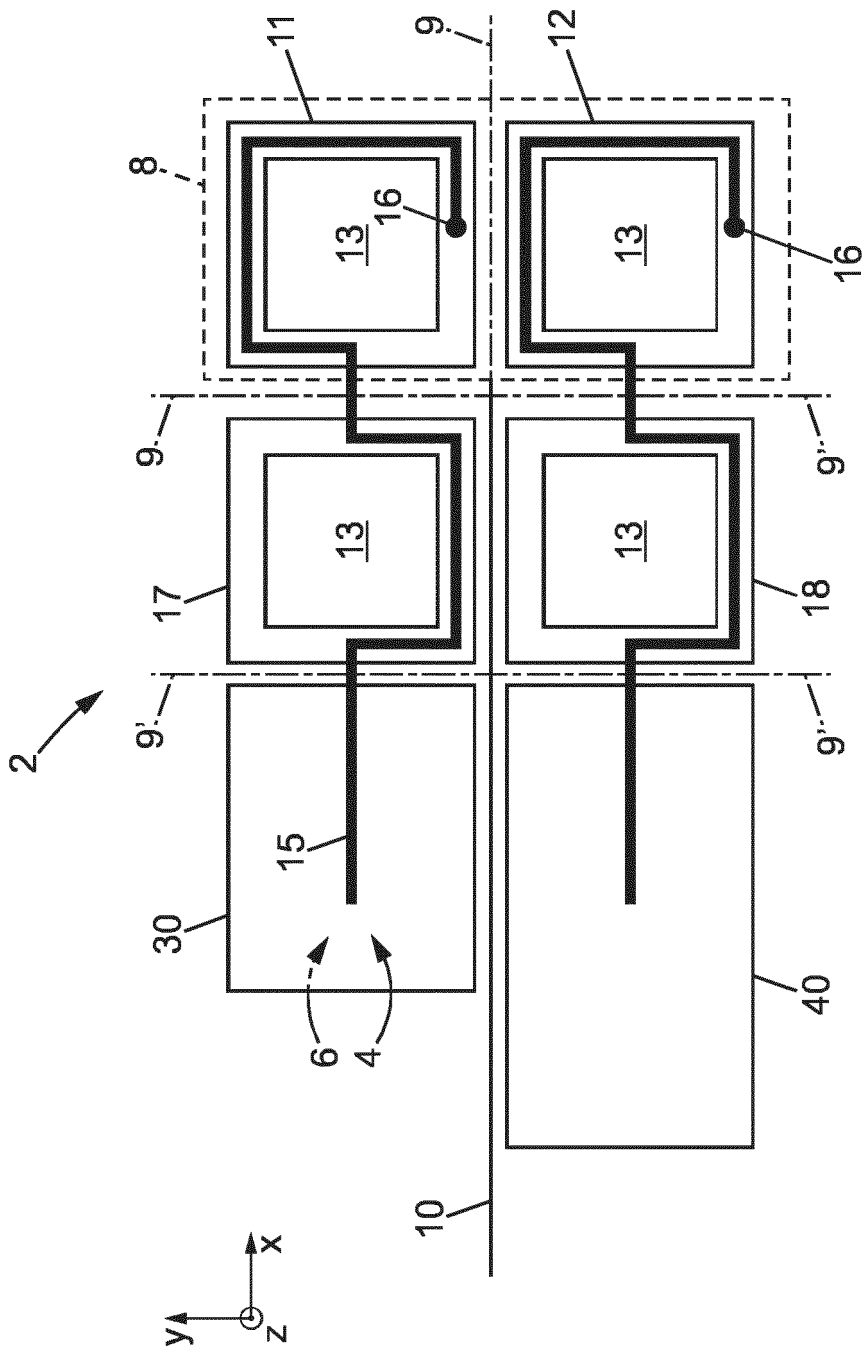


FIG. 11

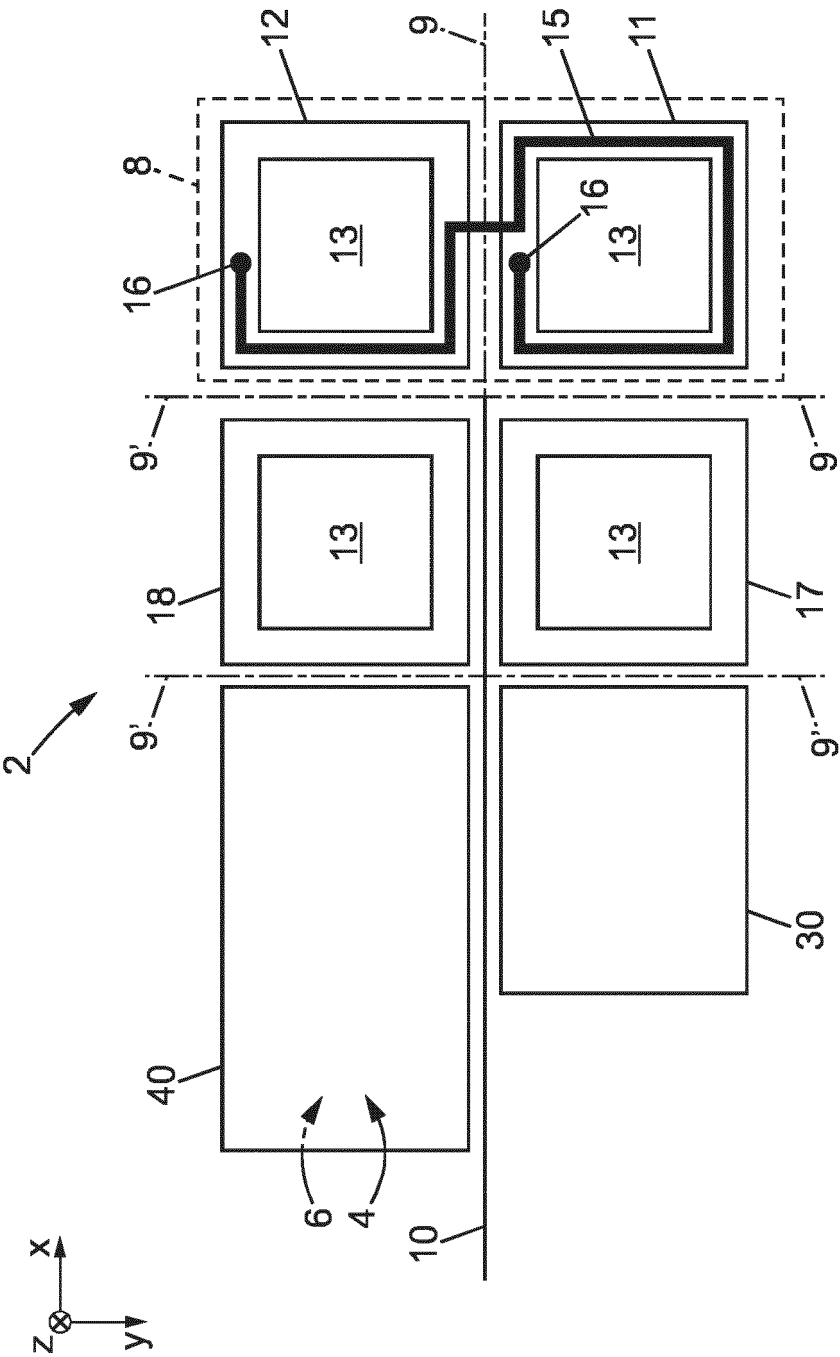


FIG. 12

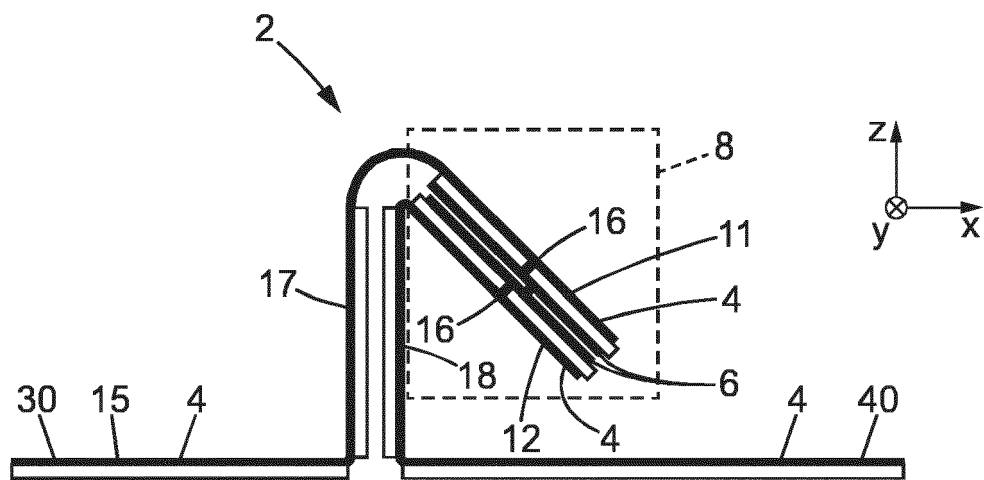


FIG. 13

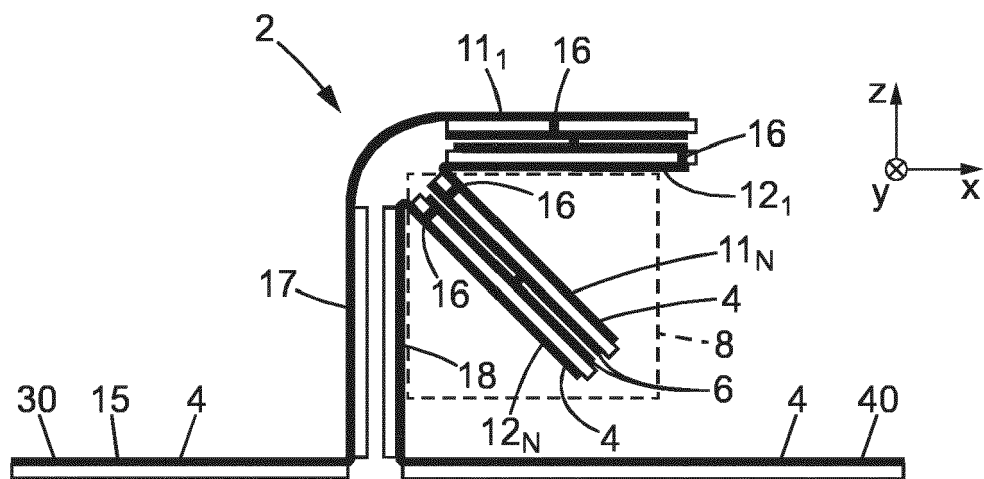


FIG. 16

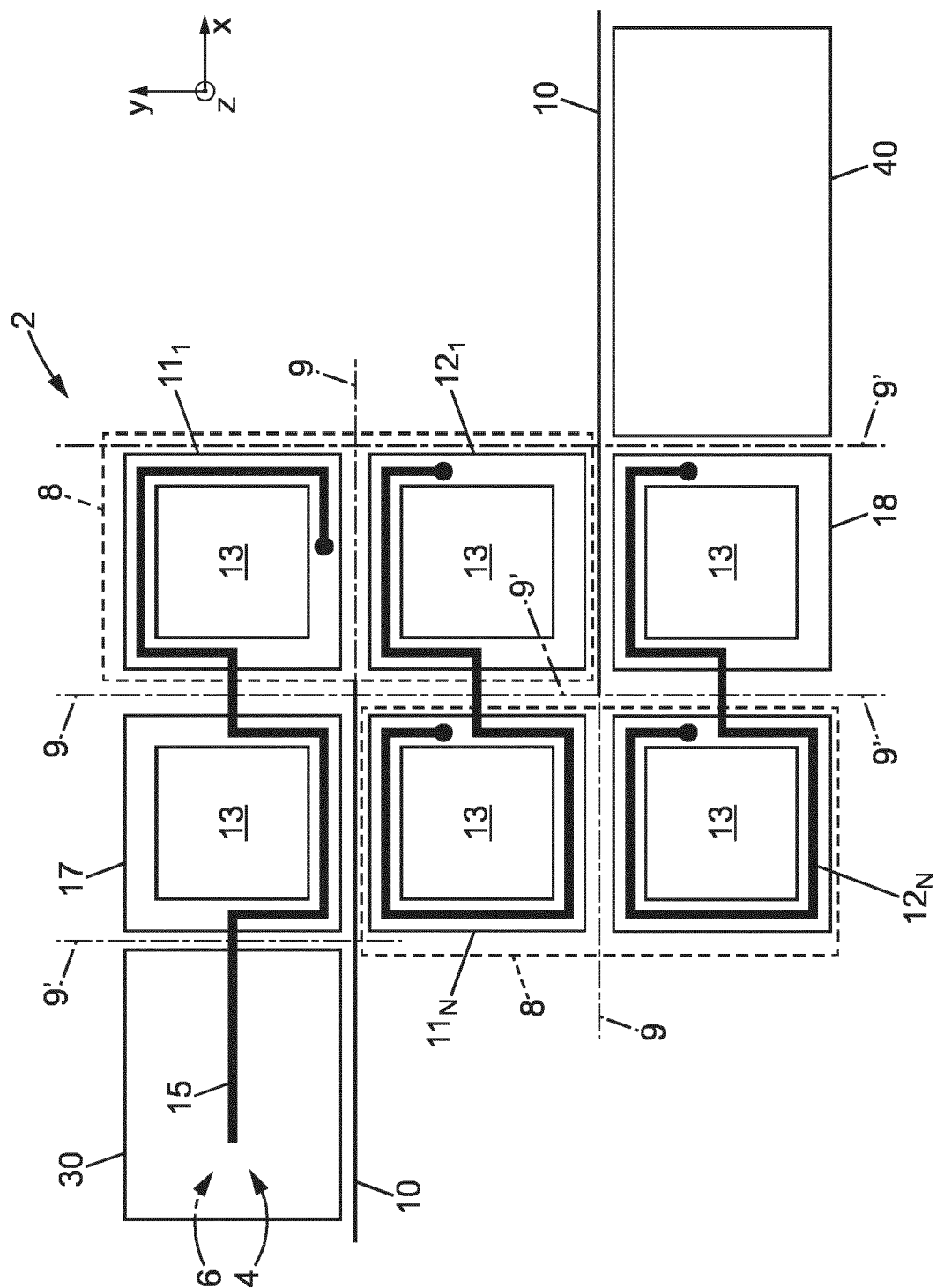
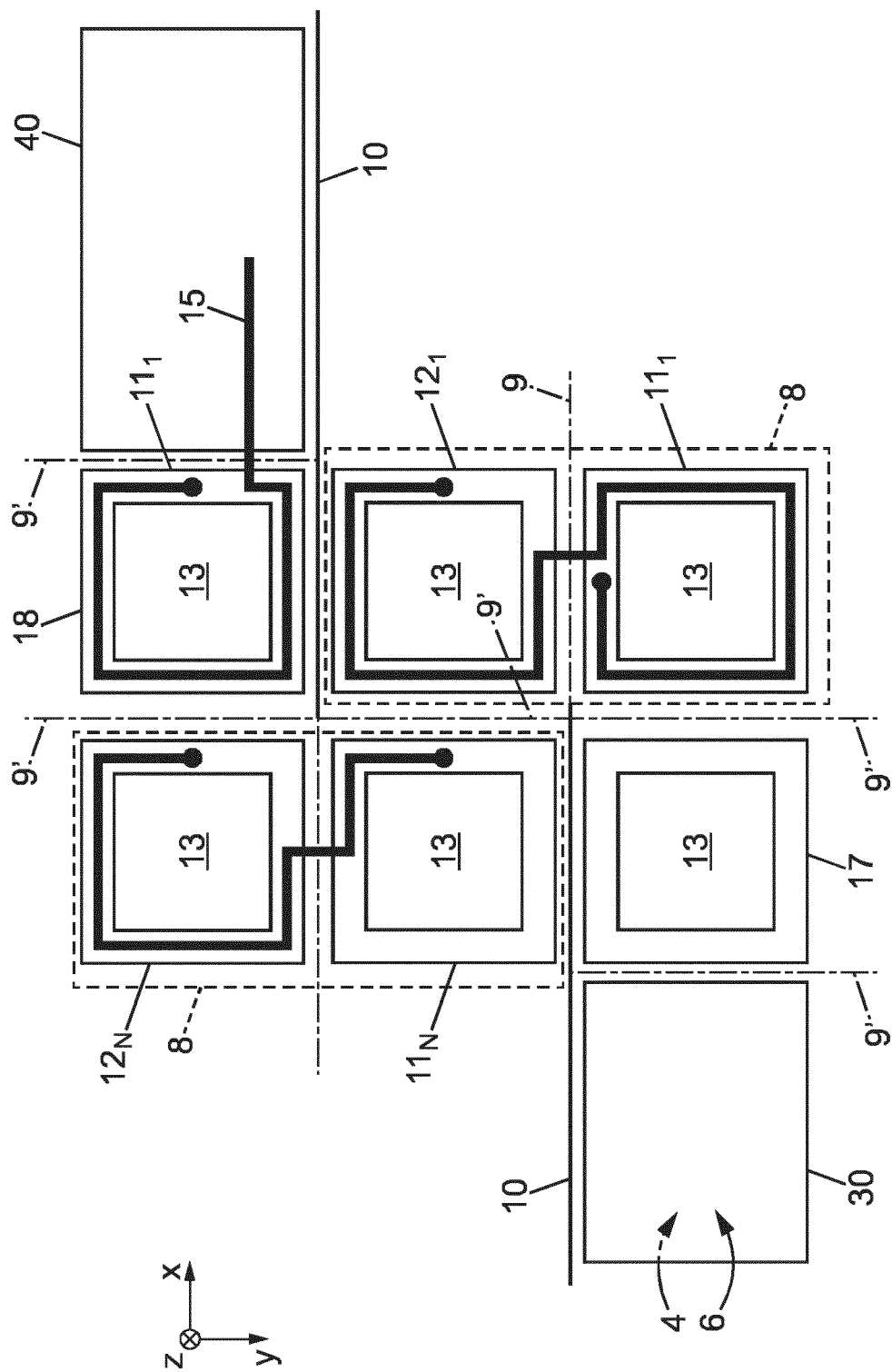


FIG. 14



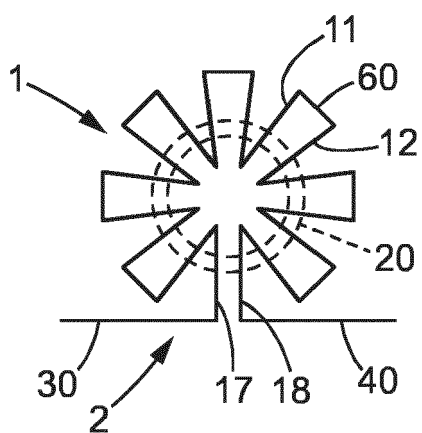


FIG. 17

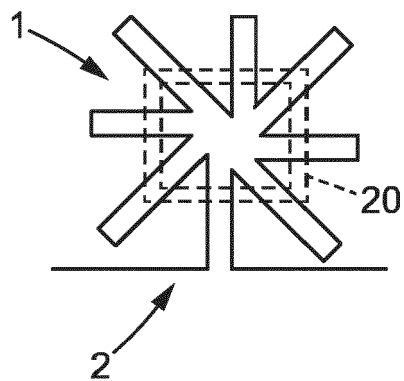


FIG. 18

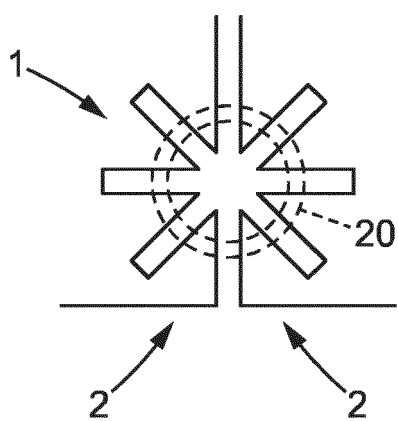


FIG. 19

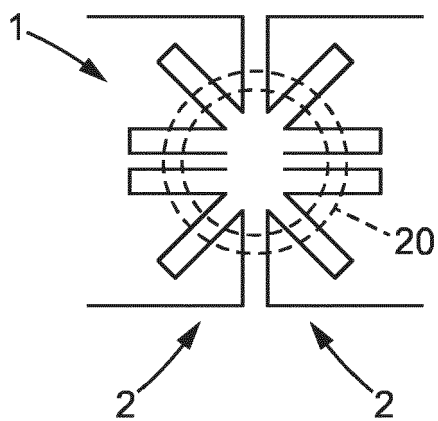


FIG. 20



EUROPEAN SEARCH REPORT

 Application Number
 EP 17 30 5174

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2 911 605 A (WALES JR NATHANIEL B) 3 November 1959 (1959-11-03) * column 1, lines 15 - 17, 37 - 42 * * column 2, lines 1 - 11, 46 - 52 * * column 3, lines 24 - 34 * * figures 1, 3, 4 *	1-10,16	INV. H01F17/00
X	WO 02/39467 A1 (PROFEC TECHNOLOGIES OY [FI]; SIPPOLA MIKA MATTI [FI]; MCGRANE KEVIN [G]) 16 May 2002 (2002-05-16) * page 1, lines 3 - 6, 21 - 31 * * page 2, lines 1 - 8 * * page 3, lines 12 - 22 * * page 5, lines 3 - 14 * * page 14, lines 11 - 18 * * page 17, lines 22 - 24 * * page 19, line 23 - page 20, line 9 * * page 25, lines 28 - 32 * * page 30, line 25 - page 41, line 4 * * figures 6 - 8, 17, 18, 40, 57 - 59 *	1-9,11,16 12-15,17	
X	EP 2 109 120 A1 (PANASONIC ELEC WORKS CO LTD [JP]) 14 October 2009 (2009-10-14) * paragraphs [0001], [0002], [0011] - [0013], [0019], [0047], [0048] * * figures 1, 2, 10 *	1-3,5-9,16	TECHNICAL FIELDS SEARCHED (IPC) H01F H05K H01K
X	US 2012/029343 A1 (WASSON JAMES R [US] ET AL) 2 February 2012 (2012-02-02) * paragraphs [0001] - [0006], [0028], [0033], [0041], [0045], [0075] * * figures 4, 5 *	1-9,16	
A	US 2001/043135 A1 (YAMADA KATSUO [JP] ET AL) 22 November 2001 (2001-11-22) * paragraphs [0001], [0010], [0079] - [0082] * * figure 8 *	1-17	
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 July 2017	Examiner Van den Berg, G
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	



EUROPEAN SEARCH REPORT

Application Number
EP 17 30 5174

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	JP H04 206906 A (TOKIN CORP) 28 July 1992 (1992-07-28) * abstract * -----	1-16	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 27 July 2017	Examiner Van den Berg, G
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	

EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 17 30 5174

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

27-07-2017

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2911605 A	03-11-1959	NONE	
WO 0239467 A1	16-05-2002	AT 373865 T AU 1249002 A DE 60130572 T2 EP 1332503 A1 GB 2373101 A US 2004075525 A1 US 2005140487 A1 WO 0239467 A1	15-10-2007 21-05-2002 03-07-2008 06-08-2003 11-09-2002 22-04-2004 30-06-2005 16-05-2002
EP 2109120 A1	14-10-2009	CN 101617374 A EP 2109120 A1 JP 5139685 B2 JP 2008186848 A US 2010079232 A1 WO 2008091006 A1	30-12-2009 14-10-2009 06-02-2013 14-08-2008 01-04-2010 31-07-2008
US 2012029343 A1	02-02-2012	US 2012029343 A1 WO 2012015502 A2	02-02-2012 02-02-2012
US 2001043135 A1	22-11-2001	CN 1324081 A JP 3624840 B2 JP 2002043138 A TW I221298 B US 2001043135 A1	28-11-2001 02-03-2005 08-02-2002 21-09-2004 22-11-2001
JP H04206906 A	28-07-1992	JP 2971943 B2 JP H04206906 A	08-11-1999 28-07-1992

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2006077163 A [0049]
- WO 2006077164 A [0049]
- WO 2006077167 A [0049]