(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 June 2021 (24.06.2021)

WIPO | PCT

(10) International Publication Number
WO 2021/123711 A1

(51) International Patent Classification:
H01M 50/213 (2021.01) *H01M 2/10* (2006.01)
H01M 50/503 (2021.01) *H01M 2/20* (2006.01)
H01M 50/509 (2021.01)

(21) International Application Number: PCT/GB2020/052564

(22) International Filing Date: 14 October 2020 (14.10.2020)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1918797.0 19 December 2019 (19.12.2019) GB

(71) Applicant: DYSON TECHNOLOGY LIMITED [GB/GB]; Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

(72) Inventors: STRUTT, Oliver; Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB). GASKELL, Christopher; Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

(74) Agent: BOOTH, Andrew et al.; Intellectual Property Department, Dyson Technology Limited, Tetbury Hill, Malmesbury Wiltshire SN16 0RP (GB).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: BATTERY MODULE AND BATTERY PACK

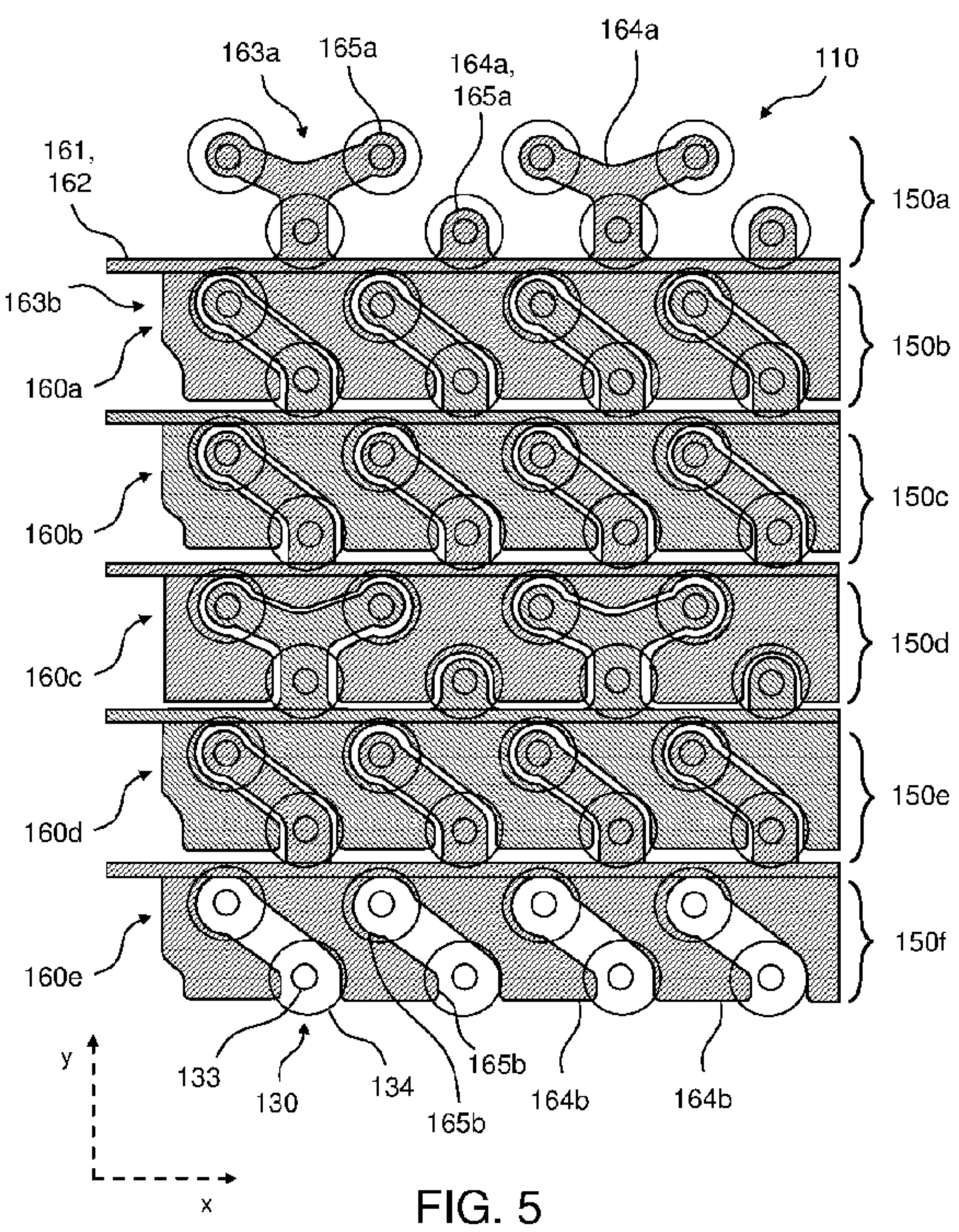

FIG. 5

(57) Abstract: Disclosed is a battery module (110) having a support (120), a plurality of battery cells (130) arranged in rows on the support (120), and at least one busbar (160) electrically connecting the battery cells (130) to form a plurality of banks of parallel-connected battery cells. Each bank has battery cells (130) in at least two of the rows. The at least one busbar (160) has a spine (162), a positive connection portion (163a) extending from a first side of the spine (162) and connected to positive terminals (133) of at least two battery cells (130) in different rows of a first bank of parallel-connected battery cells; and a negative connection portion (163b) extending from a second, opposing side of the spine (162) and connected to negative terminals (134) of at least two battery cells (130) in different rows of a second bank of parallel-connected battery cells.

WO 2021/123711 A1

[Continued on next page]

Published:
— *with international search report (Art. 21(3))*

BATTERY MODULE AND BATTERY PACK

TECHNICAL FIELD

The present invention relates to batteries and, particularly, but not exclusively, to a battery module and a battery pack comprising the battery module. The battery module and the battery pack are suitable for an electric vehicle, among other uses.

BACKGROUND

Batteries are an integral part of many electrical and electronic systems, including electric vehicles and energy storage devices. Battery packs may often be comprised of a plurality of individual battery cells electrically connected to form one or more battery modules. It can be challenging to electrically connect the battery cells in such a way as to provide a desired electrical output of a battery module in an efficient manner whilst reducing losses, weight and cost, and improving ease of manufacture.

Therefore, there is a desire to provide a practical and reliable battery pack, which is easily manufactured and operates efficiently. Reducing a weight of battery packs is a desire in the field of electric vehicles, to improve both performance and efficiency of the electric vehicles.

SUMMARY

According to a first aspect of the present invention, there is provided a battery module comprising a support, a plurality of battery cells arranged in rows on the support, and at least one busbar electrically connecting the battery cells to form a plurality of banks of parallel-connected battery cells, each bank comprising battery cells in at least two of the rows. The at least one busbar comprises a spine, a positive connection portion extending from a first side of the spine and connected to positive terminals of at least two battery cells in different rows of a first bank of parallel-connected battery cells, and a negative connection portion extending from a second, opposing side of the spine and connected to negative terminals of at least two battery cells in different rows of a second bank of parallel-connected battery cells.

In this way, the at least one busbar may be configured to electrically connect the positive terminals of the battery cells in the first bank of battery cells in parallel, and the negative terminals of the battery cells of the second bank of battery cells in parallel, and to electrically connect the first and second banks in series. The second bank of battery cells may be adjacent to the first bank.

The at least one busbar may comprise an equal number of positive connection portions and negative connection portions. The at least one busbar may comprise an equal number of connections, in the aggregate, on opposite sides of the spine at any particular point along the spine. In this way, current may flow across the spine from the positive connection portion to the negative connection portion.

The battery module may be for an electric vehicle.

The battery module may comprise at least one busbar comprising a generally straight, elongate spine, and at least one other busbar comprising a crooked spine.

The straight spine may be adjacent to a single row of battery cells. The crooked spine may comprise at least a first part adjacent to battery cells in a first row of battery cells, and a second part, offset from the first part and adjacent to battery cells in a second row of battery cells. A crooked spine may allow for parallel connection of battery cells in non-adjacent rows, without requiring connection portions which extend from the spine by too great an extent.

The spine of the at least one busbar may be configured to bridge underlying battery cell terminals.

In other words, the at least one busbar may be configured so that the spine of the at least one busbar is located above and spaced away from underlying battery cell terminals, so that the spine does not contact underlying battery cell terminals. In this way, current may flow across the spine from the positive connection portion to the negative connection portion, and between battery cells connected thereto.

Each battery cell may comprise a first end and a second end, wherein the first end comprises the positive and negative terminals of the battery cell and the second end is mounted to the support.

The battery cells may be hexagonally close packed on the support. The battery module may comprise a plurality of battery cell groups, each battery cell group comprising a plurality of rows of battery cells electrically connected by a respective at least one busbar. The support may be planar and may comprise opposing first and second faces. A first plurality of cell groups may be mounted on the first face and a second plurality of cell groups may be mounted on the second face. Adjacent cell groups on the same face may be spaced apart to form a respective channel therebetween. The support may be a cooling plate.

The first ends of the battery cells may be coplanar. The positive and negative connection portions may be coplanar. The spine may be in a plane spaced parallel to and above the connection portions.

The first ends of the battery cells and the positive and negative connection portions may be located in a first plane, and the spine may be located in a second plane spaced parallel to and above the first plane. The positive and negative connection portions may comprise bridge portions which extend from the first plane, towards the second plane. The bridge portions by extend up to or above the second plane.

One or more of: a first end of a battery cell; a positive connection portion; and/or a negative connection portion may be located slightly above or below the first plane, for instance up to twice, up to five-times, or up to ten times an average thickness of the or each busbar above or below the first plane.

For each battery cell, the positive terminal may comprise one of a central projection on the first end of the battery cell and an annular portion on the first end of the battery cell, the annular portion concentric around the central projection. The negative terminal may comprise the other of the central projection and the annular portion.

The annular projection may be defined by a rim, or an edge, of an outer shell, or canister of the battery cell.

The battery module may comprise a plurality of busbars and each battery cell may be connected to a positive connection portion of a first busbar and a negative connection portion of a second busbar adjacent the first busbar. For respective positive and negative connections to each battery cell, the positive connection portion of the first busbar and the negative connection portion of the second busbar may be mutually shaped to be spaced from and conform to one another.

There may be a gap between positive and negative connection portions to maintain electrical isolation, for instance to prevent a short-circuit.

The battery module may comprise a single layer of busbars. The connection portions of each busbar may be coplanar with the connection portions of each other busbar. The spine portion of each busbar may be coplanar with the spine portion of each other busbar.

Arranging the busbars in a single layer may remove a requirement to provide insulation between busbars, thereby reducing a complexity of the battery module and reducing material cost.

One or more of the busbars, or portions thereof, may be located slightly above or below one other busbar in the same plane, for instance up to twice, up to five-times, or up to ten times an average thickness of the or each busbar above or below the first plane. This slight deviation may still be considered broadly to constitute a single layer.

The positive and negative connection portions may each comprise a respective one or more positive and negative lateral projections arranged along the respective first and second sides of the spine.

A positive lateral projection may be electrically connected to positive terminals of one or more battery cells, and a negative lateral projection may be electrically connected to negative terminals of one or more battery cells. The positive and negative lateral projections may provide a flexible, or resilient, cantilever extending from the spine. This may facilitate an attachment of the lateral projections to respective battery cell terminals, such as by welding portions of the lateral projection to the battery cell terminals.

The at least one busbar may comprise positive and negative lateral projections of different shapes.

The at least one busbar may comprise a repeating pattern of positive and negative lateral projections along the spine.

In this way, the busbars may be formed / stamped out of a single sheet from a repeating template. This may lead to less wasted material and a lower cost of manufacture.

The battery module may comprise a plurality of busbars, and positive lateral projections of a first busbar may interleaved with negative lateral projections of a second, adjacent busbar.

Negative lateral projections of the first busbar may be interleaved with positive lateral projections of a third adjacent busbar.

Each positive lateral projection may comprise at least one positive contact for electrically connecting to a positive terminal of a respective at least one battery cell, and each negative lateral projection may comprise at least one negative contact for electrically connecting to a negative terminal of a respective at least one other battery cell.

Each positive contact may be suitably shaped and arranged to electrically connect the positive lateral projection to a respective battery cell. Each negative contact may be suitably shaped and arranged to electrically connect the negative lateral projection to a respective battery cell.

The at least one positive contact may comprise a circular portion and the at least one negative contact may comprise a semi-annular portion when viewed in a direction orthogonal to a plane of the busbar.

In this way, the positive and negative contacts may be shaped to conform to the shapes of respective positive and negative terminals, thereby ensuring reliable connections and improving manufacturing efficiency.

The at least one positive lateral projection may comprise two or more positive contacts for connecting to positive terminals of a respective two or more battery cells, and at least one negative lateral projection may comprise two or more negative contacts for connecting to negative terminals of a respective two or more other battery cells.

The two or more battery cells may be in the same row or in different rows.

The at least one busbar may have an equal number of positive and negative contacts.

The at least one busbar may comprise an equal number of connections, in the aggregate, on opposite sides of the spine at any point along the spine. In this way, current may flow across the spine, and current flow along the spine may be reduced. This may improve an accuracy of characteristics sensed at an end of the spine.

The positive and negative contacts may be welded to respective battery cell terminals to maintain an electrical contact.

The positive contacts may comprise an aperture through which at least a part of the weld is visible.

The negative contacts may comprise an aperture through which at least a part of the weld is visible. In this way, a quality of the weld may be checked.

The positive and negative connection portions may comprise respective positive and negative bridge portions, each positive and negative bridge portion extending above and spaced away from underlying battery cell terminals.

The at least one busbar may be configured so that the positive and negative bridge portions do not contact underlying battery cell terminals. The spine may be spaced above and away from underlying battery cells. One or more positive bridge portions may connect a respective one or more positive contacts to the spine. One or more negative bridge portions may connect a respective one or more negative contacts to the spine.

The battery module may comprise at least two busbars having the same form and/or at least two busbars that generally tessellate with one another.

In this way, multiple busbars may be formed or stamped from the same sheet of material, such as by using a template. This may lead to less wasted material and a lower cost of manufacture.

The battery cells may be arranged in rows at least in part by a battery cell carrier, the battery cell carrier comprising plurality of apertures and each aperture comprising a respective battery cell passing therethrough.

The at least one busbar may comprise mounting, or fixing, features disposed along the spine for fixing the at least one busbar to the cell carrier.

The battery cell carrier may comprise one or more fixing features corresponding to the one or more fixing features of the at least one busbar, and the at least one busbar may be mounted to the battery cell carrier and aligned relative to the plurality of battery cells by the corresponding fixing features.

The battery cells may be held in the battery cell carrier by adhesive, and the at least one busbar may comprise one or more adhesive insertion apertures for providing access to adhesive wells of the battery cell carrier, the adhesive wells configured to distribute adhesive to battery cells in the battery cell carrier.

The at least one busbar may cover, or the plurality of busbars may together cover, greater than 50%, greater than 60% or greater than 70% of the surface area of the plurality of battery cells when viewed in a direction orthogonal to a plane of the battery module.

The plane of the battery module may be defined by the support, for instance wherein the support is planar. Viewing in a direction orthogonal to the plane may comprise looking in a direction normal to the first ends of the battery cells.

According to a second aspect of the present invention, there is provided a battery pack comprising a battery module according to the first aspect of the invention.

The battery pack may be for an electric vehicle.

According to a third aspect of the present invention, there is provided an electric vehicle comprising a battery module according to the first aspect, or a battery pack according to the second aspect.

Individual battery modules of a battery pack in the electric vehicle may, conveniently, be replaceable, or may be separable from the battery pack to be used for other purposes, such as installation in an industrial or domestic energy storage system.

Further features and advantages of the invention will become apparent from the following description of examples of the invention, which is made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In order that the present invention may be more readily understood, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic view of an arrangement of battery modules in a battery pack according to an example;

Figure 2A is a schematic view of a battery module of the battery pack of claim 1, showing battery cells, busbars and circuit boards therein;

Figure 2B is an illustrative side-elevation and plan view of the battery cells of Figure 2A;

Figure 3A is a schematic view of a connector connecting a circuit board and a busbar of Figure 2A;

Figure 3B is a schematic view of an alternative arrangement of the connector of Figure 3A;

Figure 4A is a schematic isometric view of a battery cell carrier, showing a busbar and a circuit board of figure 2A mounted thereto;

Figure 4B is a cross-sectional side-elevation view of the battery cell carrier of Figure 4A;

Figure 5 is a schematic plan view of busbars connected to battery cells, according to an example;

Figure 6 is an illustrative isometric view of one of the busbars of Figure 5, according to an example;

Figure 7 is a schematic plan view of busbars connected to battery cells, according to an example;

Figure 8A is a schematic side elevation view of an electric vehicle according to an example; and

Figure 8B is a schematic plan view of an underside of the electric vehicle of Figure 8A.

DETAILED DESCRIPTION

Details of methods and systems according to examples will become apparent from the following description, with reference to the Figures. In this description, for the purpose of explanation, numerous specific details of examples are set forth. Reference in the specification to 'the example' or similar language means that a particular feature, structure, or characteristic described in connection with the example is included in at least that one example, but not necessarily in other examples. It should further be noted that the examples illustrated in the figures are described in various different ways and are described schematically with certain features omitted and/or necessarily simplified for ease of explanation and understanding of the concepts underlying the example.

Certain examples described herein relate to a battery module comprising a plurality of battery cells. The battery module may be part of an arrangement of battery modules forming at least part of a battery pack. Examples of the invention will be described in the context of an electric vehicle. It will be understood that the invention is not limited to this purpose and may be applied to supply and/or store electrical energy for any kind of industrial, commercial or domestic purpose, for example in smart grids, home energy storage systems, electricity load balancing and the like.

In the following text, the terms “battery”, “cell” and “battery cell” may be used interchangeably and may refer to any of a variety of different battery cell types and configurations including, but not limited to, lithium ion, lithium ion polymer, nickel metal hydride, nickel cadmium, nickel hydrogen, alkaline, or other battery cell type/configuration.

Figure 1 shows a schematic view of a battery pack 10 comprising an arrangement of battery modules 100a–100c and a battery management system 200. The battery modules 100a–100c may generally be referred to herein using the reference numeral 100. The battery pack 10 has a first dimension 11 and a second dimension 12, respectively, corresponding to a width and a length dimension of the battery pack 10, respectively. The first and second dimensions 11, 12 may alternatively be referred to as ‘x’ and ‘y’ dimensions. A third dimension 13, which is also referred to herein as a ‘z’ dimension, is orthogonal to the first and second dimensions 11, 12 and corresponds with a depth or height dimension of the battery pack 10. In the illustrated example, the first dimension 11 is also a minor dimension of the battery pack 10 in the x-y plane. In other examples, the first dimension 11 may be a major dimension of the battery pack 10 in the x-y plane, or the battery pack 10 may be equilateral in the x and y dimensions. As used herein, the terms “major dimension” and “minor dimension” refer, respectively, to the longest and shortest spans or lengths of a structure. The major dimension is typically (as is the case herein), but not exclusively, perpendicular to the minor dimension.

There are three battery modules 100a–100c shown in the battery pack 10, but in other examples there may be any other number of battery modules 100 in the battery pack 10. The battery modules 100a–100c of the present example each comprise a plurality of battery cells (as shown in Figure 2a) arranged into groups 110 of battery cells, referred to herein generically as “cell groups 110”. Each battery module 110a–100c of Figure 1 comprises a respective support 120a–120c and four cell groups 110 mounted on the respective support 120a–120c.

Taking one battery module 100a as an example, the battery module 100a comprises a first cell group 110a, a second cell group 110b, a third cell group 110c and a fourth cell group

110d. The support 120a of the battery module 100a is planar and comprises opposing first and second faces 121, 122. The cell groups 110a–110d are arranged with two cell groups 110a, 110b mounted spaced apart on the first face 121 of the support 120a and two cell groups 110c,110d mounted spaced apart on the second face 122 of the support 120a. In this way, a first channel 123 is defined between the cell groups 110a, 110b on the first face 121 and a second channel 124 is defined between the cell groups on the second face 122.

In the present example, each of the supports 120a–120c is also shown as being a generally regular, rectangular, plate-like member, comprising a major and a minor dimension, and supporting generally cuboidal cell groups 110a–110d. In this way, the supports are elongate. In some examples, the channels 123, 124 of a battery module 100a–100c extend in a minor dimension of a respective support 120a–120c. In some examples, any number of cell groups 110a–110d may be mounted on the support 120a. In other examples, the cell groups 110a–110d may be mounted on only one of the first and second faces 121, 122. In some examples, each of the supports 120a–120c may be a cooling member.

The battery modules 100a–100c are arranged in the battery pack 10 of Figure 1 side-by-side, width wise, adjacent to and coplanar with one another in the second dimension 12 such that the cell groups 110a–110d of each battery module 100a–100c are aligned with corresponding cell groups 110a–110d of each other battery module 100a–100c. It will be understood that the term “coplanar” as used herein is inclusive of slight deviations in a location of an element from a plane. That is, in some examples, one or more battery modules 100a–100c may be located slightly above or below a plane of the battery pack 10, for instance located a distance of up to twice or up to five times an average thickness of one or each support 120a–120c above or below a plane defined by one or more of the supports 120a–120c. In later examples relating to busbars (not shown in Figure 1), the term “coplanar” may be defined in a similar way in relation to an average thickness of busbars, rather than in relation to an average thickness of the supports 120a–120c.

As shown in the example of Figure 1, the first and second channels 123, 124 of each battery module 100a–100c in the example of Figure 1 are longitudinally aligned with corresponding first and second channels 123, 124 of each other battery module 100a–100c. The alignment of first channels 123 forms a first longitudinal passage 14 between cell groups 110a, 110b in the battery pack 10, and the alignment of second channels 124 forms a second longitudinal passage 15 between cell groups 110c, 110d in the battery pack 10. There may be more than two longitudinal passages 14, 15 or only one longitudinal passage in the battery pack 10. In other examples, there may be no longitudinal passages 14, 15 in the battery pack 10. According to the present example, the first and second longitudinal passages 14, 15 extend parallel with the second dimension 12 of the battery pack 10.

In the illustrated example, the battery modules 100a–100c are spaced apart along the second dimension 12 of the battery pack 10 to form a plurality of transverse passages 16 in the battery pack 10. The transverse passages 16 of the illustrated example extend in the first dimension 11 of the battery pack 10.

The battery management system 200 of the present example comprises a controller 210. The controller 210 is communicatively coupled to each cell group 110 in each battery module 220 by communication lines 220. In some examples, the communication lines 220 comprise wires. In other examples, the communication lines 220 comprise busbars. In other examples, communication between the controller 210 and the cell groups 110 may instead, or in addition, be wireless. The battery modules 100a–100c are electrically connected to one another and to the controller 210 by module connections 221. That is, cell groups 110 of each battery module 100 are connected to cell groups 110 of adjacent battery modules 100 via module connections 221. In the present example, the module connections 221 between cell groups 110 of adjacent battery modules 100 are located in respective transverse passages 16.

According to the example shown, each cell group 110 is connected in series to other cell groups 110 in the same row, so that an aggregate current flows in the second, major dimension 12 of the battery pack 10. Each cell group 110a–110d in a battery module 100a is electrically isolated from each other cell group 110a–110d on the same support 120a, at least until the battery module 100a is connected to other battery modules 100b, 100c in the battery pack 10. For example, cell groups 110a, 110b on the first face 121 of a support 120a at an end of the battery pack 10 in the second dimension 12 are connected to cell group 110c, 110d on the second face 122 of the support 120a. The cell groups 110a, 110c are electrically isolated from adjacent cell groups 110b, 110d on the same support 120a by a respective channel 123, 124 and/or longitudinal passage 14, 15.

In some examples, the controller 210 of the battery management system 200 is configured to vary an electrical output of the battery pack 10, and/or to reconfigure the battery pack 10. In some examples, the battery modules 100a–100c are electrically connected to a controller other than the controller 210 shown in Figure 1. In the present example, the controller 210 is configured to detect and/or monitor one or more properties of the cell groups 110 of each battery module 100a–100c, as will be described hereinafter with reference to Figure 2.

Figure 2A shows a simplified schematic view of a cell group 110, of one battery module 100a–100c of Figure 1, showing the battery cells 130 in the cell group 110. The cell group 110 comprises a plurality of battery cells 130 arranged in a two-dimensional array 140. The array 140 has a major dimension parallel to the x-axis and a minor dimension parallel to the y-axis. The battery cells 130 in the array 140 are arranged into a plurality of banks (or sub-groups) 150a–150e of battery cells 130. For clarity, the banks 150b, 150d of battery cells 130 in Figure 2A are filled white and the banks 150a, 150c, 150e are hatched to distinguish the banks 150a–150e of battery cells 130 from one another. The banks 150a–150e may generally be referred to herein using the reference numeral 150.

The example illustrated in Figure 2A shows five banks 150a–150e of parallel-connected battery cells 130, each bank 150a–150e comprising eight or nine battery cells 130. In other examples, there may be any number of such banks 150a–150e and any number of battery cells 130 in each bank 150a–150e. Furthermore, in the present example, the battery cells 130 are arranged into rows, the rows extending in the major dimension of the array 140. The banks 150a–150e span a length of the cell group 110 in the major dimension, and each bank 150a–150e is confined to a single row in the array 140. As illustrated, each bank 150a–150e is generally a one-dimensional rectangular array. It will be understood that, in other examples, each bank 150a–150e of parallel-connected battery cells 130 may not span the entire length of the cell group 110 in the major dimension thereof, and/or that the banks 150a–150e may span multiple rows in the array 140, and/or may not be confined to such rows or rectangular arrays. That is, in other examples, each of the banks 150a–150e comprise battery cells in two or more rows.

Figure 2B shows a side-elevation and a plan view of a battery cell 130. The battery cell 130 comprises a first end 131 and a second end 132, opposite to the first end 131. The second ends 132 of each of the battery cells 130 in the cell group 110 are secured, in this example, to a face 121, 122 of a respective support 120a–120c, whereby the first ends 131 of the battery cells 130 are generally coplanar, residing in a plane that is parallel to a plane of the respective support 120a–120c.

The battery cells 130 of the present example each comprise first polarity 133 and second polarity 134 battery cell terminals at respective first ends 131, the first polarity and second polarity terminals 133, 134 being of opposite polarity. The battery cell terminals 133, 134 of each of the battery cells 130 are exposed on the first ends 131 of the battery cells 130, away from respective supports 120a–120c. In the present example, the first polarity terminal 133 is a positive terminal 133 of the battery cell 130, and the second polarity terminal 134 is a negative terminal 134 of the battery cell 130. It will be understood that, in other examples, the polarities of the battery cell terminals 133, 134 may be reversed.

In the present example, for each battery cell 130, the positive terminal 133 comprises a central projection 133 on the first end 131 of the battery cell 130 and the negative terminal 134 comprises an annular portion 134 on the first end 131 of the battery cell 130 around the central projection 133. The annular portion 133 is defined by a rim, or an edge, of an outer shell, or canister of the battery cell 130. It will be understood that the positive and negative battery cell terminals 133, 134 of the battery cells 130 of the present invention are not limited to such shapes and may instead be any other shape suitable for facilitating respective positive and negative connections to the battery cells 130.

According to the present example, the battery cells 130 of a cell group 110 are mounted on a respective support 120a–120c by any method, including but not limited to, the use of adhesive, fixing mechanisms such as clasps, clamps, braces, or any other suitable attachment mechanisms. The battery cells 130 are supported at respective second ends 132 in a tray (not shown in Figure 2B). The tray comprises a plurality of recesses into each of which is received the second end 132 of a respective battery cell 130. The tray is mounted to a respective support 120a–120c. In other examples, the tray may not exist, and the respective support 120a–120c may be formed to receive the battery cells 130. That is, the respective support 120a–120c may have least one recess into which a battery cell 130 or a cell group 110 is received and mounted thereon.

According to the present example, the supports 120a–120c are constructed from electrically conductive material, and battery cells 130 are electrically isolated from the supports 120a–120c by the tray, which is constructed from electrically insulative material. In the present example, the tray is thermally conductive. In other examples, the tray may be thermally insulative. In other examples, the supports 120a–120c may not be electrically conductive.

Returning to Figure 2A, the cell group 110 of the illustrated example comprises a plurality of busbars 160, specifically four busbars 160a–160d. We herein refer generally to any one or more of the busbars 160a–160d with the reference numeral 160. Each busbar 160 electrically connects, in parallel, battery cells 130 in at least one bank 150a–150e of battery cells. As such the busbars 160 extend in the major dimension of the cell group 110. The busbars 160 further connect adjacent banks 150a–150e of parallel-connected cells together in series. In other examples, there may be any number of busbars 160, such as more than four or fewer than four, such as only one busbar 160. In the present example, each busbar 160 is an elongate electrically conducting wire, plate or rod with connections (not yet shown in detail) to positive or negative battery cell terminals 133, 134 of the battery cells 130 in a bank 150a–150e.

More specifically, one busbar 160a in the illustrated example is configured to connect the positive battery cell terminals 133 of each battery cell 130 in one bank 150a of battery cells 130 to the negative battery cell terminal 134 of each battery cell 130 in an adjacent bank 150b of battery cells 130.. In some examples, a busbar 160 on a periphery of the cell group 110 (not shown in Figure 2A) is configured to connect the battery cells 130 of a respective peripheral bank 150a, 150e of battery cells 130 to one another in parallel. In some examples, peripheral busbars 160 are configured to facilitate a connection between cell groups 110 of adjacent battery modules 100, for example via the module connections 221.

In the illustrated example, the banks 150a–150e of battery cells 130 are connected such that current flows in series, via the busbars 160, between banks 150a–150e in the minor dimension of the cell group 110, as indicated by the arrow labelled I in Figure 2A. As such, the current flow in a cell group 110 is, in the aggregate, perpendicular to a major dimension of each of the busbars 160, which are elongate and extend in the major dimension of the cell group 110. In other words, the aggregate current flow in the cell group 110 is distributed evenly across the major dimension of the cell group 110. The direction is said to be ‘in the aggregate’, or ‘on average’, as there may be some minor deviations in current flow direction, for instance, which may be determined by the particular arrangement of the battery cells 130 and/or the shape of the busbars 160 connecting the battery cells 130, as will be described hereinafter with reference to Figures 4 to 5.

Having elongate busbars 160 spanning the major dimension of a cell group 110, while having an aggregate current spread across the minor dimension of the cell group 110, enables the thickness of the busbars 160 to be reduced (compared with having busbars 160 spanning the minor dimension and having an aggregate current flowing in the major dimension), whilst maintaining a desired cross-sectional area and current density. The illustrated example comprises cell groups 110 having an aspect ratio of approximately 3:1 (that is, having a major dimension three times longer than a minor dimension). The cell groups 110 may therefore comprise busbars 160 which are in the order of three times thinner than those that would be required for a cell group 110 with an aspect ratio of 1:1, whilst providing the same current density in the busbars 160. Thus, busbars 160 may be thinner and lighter per unit area, which means they require less space per unit area and may be more easily formed, for instance, for the purposes of connecting to the terminals 133, 134 of individual battery cells 130. Furthermore, a shorter aggregate current path in a cell group 110 may lead to a reduced electrical resistance in the busbars 160, as resistance is proportional to the length of the current path.

The battery management system 200 comprises a circuit board 230, as shown in figure 2A, connected to the busbars 160a–160d of a cell group 110 via respective busbar tabs 161a–161d. That is, each busbar 160a–160d comprises a respective tab 161a–161d extending from the busbar 160a–160d, and the tab 161a–161d is electrically connected to the circuit board 230. The tab 161a–161d is located at an end of the busbar 160a–160d and extends from the busbar 160a–160d in a direction orthogonal to the direction of the aggregate current flow in the busbar 160a–160d. That is, each tab 161a–161d is a longitudinal extension of a respective busbar 160a–160d in first direction, and current flows in a second direction that is orthogonal to the first direction. One or more of the busbar tabs 161a–161d may generally be referred to herein using the reference numeral 161.

Each tab 161a–161d is disposed in the same plane as a respective busbar 160a–160d and thereby in the same plane as the aggregate current flow through the respective busbar 160a–160d. In other examples, the tab 161a–161d may be disposed in a plane offset and parallel to the aggregate current flow through the respective busbar 160a–160d. In yet other examples, the tab 161a–161d may be located on a central portion of the busbar 160a–160d, away from an end of the busbar 160a–160d. In some examples, the tab 161a–161d is upstanding.

In the present example, the tab 161a–161d of each busbar 160a–160d in each cell group 110 in the battery pack 10 extends into a respective channel 123, 124 defined between the cell group 110 and an adjacent cell group 110. The circuit board 230 connected to the busbars 160a–160d is then, conveniently, located in the channel 123, 124 and thereby in a longitudinal passage 14, 15 of the battery pack 10.

The circuit board 230 of the present example comprises apertures 231a–231d (generally referred to herein as "apertures 231"), through each of which a respective busbar tab 161a–161d passes. Figure 3A shows a side-on illustrative view of a busbar tab 161 passing through an aperture 231 of the circuit board 230. The busbar tab 161 is secured to the circuit board 230 by a clip 232 located on a side of the circuit board 230 away from the busbar 160 from which the tab 161 extends. In other examples, the clip 232 may be located on the same side of the circuit board 230 as the busbar 160. In the present example, the clip 232 electrically connects the circuit board 230 to the tab 161. In this way, a voltage in the respective busbar 160 may be detected via the tab 161 and the circuit board 230. In other examples, the clip 232 may be electrically insulating.

Figure 3B shows the circuit board 230 connected to a busbar tab 161 in an alternative arrangement, according to another example. In this example, the circuit board 230 does not comprise an aperture 231 for receiving a respective busbar tab 161a–161d. Rather, the busbar tab 161 extends towards the circuit board 230 and is secured to the circuit board 230 by a respective clip 232 located on the same side of the circuit board 230 as the tab 161.

Although not shown in Figure 2A, the circuit board 230 comprises a plurality of clips 232, each configured to connect to a respective tab 161a–161d. The clips 232 provide a secure yet conveniently removable connection between the circuit board 230 and respective busbar tabs 161.

Returning to Figure 2A, the battery management system 200 is configured to detect and/or monitor one or more properties of the busbars 160a–160d, for instance in order to monitor a performance of a respective cell group 110 and/or battery module 100a–100c of Figure 1. In the present example, the battery management system 200 comprises a plurality of circuit boards 230, each connected to a respective cell group 110 in the battery pack 10. In other examples, there may be any number of circuit boards 230, for instance to monitor properties of any number of cell groups 110 and/or battery modules 100a–100c.

As described hereinbefore, the circuit board 230 connected to the cell group 110 of Figure 2A comprises a clip 232 electrically connected to a respective busbar 160. The battery management system 200 of the present example is configured to detect a voltage of each busbar 160a–160d in the cell group 110 via respective busbar tabs 161a–161d, clips 232 and the circuit board 230. In this way, the circuit board 230 comprises a voltage sensor at least in part defined by the clips 232. In some examples, the controller 210 of the battery management system 200 determines and/or monitors an integrity or performance of a busbar 160a–160d or battery cell 130 connected thereto, on the basis of the sensed voltage. In other examples, the controller 210 determines and/or monitors an output of a respective cell group 110 on the basis of sensed voltages.

The circuit board 230 comprises sensors for detecting the properties of respective busbars 160a–160d. In the present example, the circuit board 230 comprises a plurality of temperature sensors 233a–233d, such as thermistors, each temperature sensor 233a–233d configured to sense a temperature of a respective busbar 160a–160d via respective tabs 161a–161d. In some examples, the circuit board 230 comprises a single temperature sensor 233a–233d configured to detect a temperature of one or more of the busbars 160a–160d. In the illustrated example, the temperature sensors 233a–233d are located in close proximity to the tabs 161a–161d of respective busbars 160a–160d. In this way, an accuracy of a temperature sensed in a region of a tab 161a–161d may be improved. In some examples, the controller 210 of the battery management system 200 determines and/or monitors an integrity of the busbar on the basis of the sensed temperature. In other examples, the controller 210 monitors and/or controls operation of a cooling system via a feedback loop on the basis of the sensed temperature.

The battery management system 200 of the present example is thus configured to detect and/or monitor one or more properties of busbars 160 in the battery pack 10, for instance in order to monitor a performance of respective battery modules 100a–100c. As described hereinbefore, an amount of current flowing in the major dimension of each busbar 160a–160e of the cell group 110 is reduced. In this way, fluctuations in signals representing properties sensed by the circuit board 230, via the tabs 161a–161d, is minimised, thereby improving a reliability of the detection of busbar 160a–160d properties, such as voltage, by the battery management system 200.

In the illustrated example, an aggregate current flows along each row of cell groups 110 in the major dimension of the battery pack 10. The battery modules 100a–100c are connected so that an aggregate current in each row flows in a direction opposite to that in each adjacent and over and underlying row. Magnetic fields (not shown in the figures) are generated by the aggregate current flows in respective rows. The magnetic field generated in each row has an opposite polarity to that of each adjacent and over and underlying row, due to the different directions of aggregate current flow. Therefore, the magnetic field of each row interacts with that of other rows in the region of the channels 123, 124 and longitudinal passages 14, 15. The interacting magnetic fields at least partially cancel one another out, leading to a region of reduced magnetic field in each channel 123, 124 and longitudinal passage 14, 15.

In the illustrated example, each circuit board 230 in the battery pack 10 is located in a channel 123, 124 and in a longitudinal passage 14, 15. In this way, each of the circuit boards 230, and/or other electronic or electrical components located within a longitudinal passage 14, 15, experiences a reduced magnetic interference. This may improve a reliability of the sensing by the circuit boards 230 and improved performance of the battery management system 200 as a whole.

In the present example, the battery cells 130 in a cell group 110 are supported at the first end 131 by a battery cell carrier. Figure 4A shows a schematic isometric view, and Figure 4B shows a cross-sectional view, of a part of the cell group 110 showing a simplified battery cell carrier 300. The battery cell carrier 300 comprises a plurality of carrier apertures 310, each carrier aperture 310 supporting a battery cell 130 and configured to permit access to respective battery cell terminals 133, 134. The battery cell carrier 300 comprises busbar mounting features in the form of busbar mounting projections 320 for mounting the busbars 160. The busbars 160 comprise corresponding mounting features in the form of busbar mounting apertures 169for receiving the busbar mounting projections, as will be described in more detail hereinafter with reference to Figure 6. The busbar mounting projections 320 each comprise a deformed region 321 for securing the busbar 160 to the battery cell carrier 300.

The battery cell carrier 300 comprises circuit board mounting features in the form of circuit board mounting projections 330 for mounting the circuit board 230. The circuit board 230 comprises corresponding circuit board mounting features in the form of circuit board mounting apertures 234 for receiving the circuit board mounting projections 330 from the battery cell carrier 300. In this way, the circuit board mounting projections provide structural support for the circuit board 230. The circuit board 230 of the present example is planar and is mounted orthogonal to a plane of the cell group 110, the tabs 161 and/or the busbars 160.

Figure 5 shows a top-down schematic view of at least a part of a cell group 110 according to an example. For ease of understanding, features of the cell group 110 which are similar to those of previous examples have been given the same reference numerals. The cell group 110 comprises a plurality of battery cells 130 arranged into six banks 150a–150f of battery cells 130 on a support 120 (not shown). The battery cells 130 are arranged into rows on the support, and each bank 150a–150f comprises cells in two of the rows. In other examples, each bank 150a-150f may comprise cells in more than two of the rows, or in a single row.

The battery cells 130 in each bank 150a–150f are electrically connected in parallel, and the banks 150a–150f are electrically connected in series, by a plurality of busbars 160, in this case five busbars 160a–160e. In other examples, there may be more than six or fewer than six banks 150 of battery cells, and/or more than five or fewer than five busbars 160. Adjacent busbars 160a–160e in Figure 5 are hatched in different directions, to aid in differentiating the busbars 160a–160e. Underlying battery cell terminals 133, 134 are shown with solid lines. Figure 6 shows a schematic isometric view of a portion of one of the busbars 160a–160e of Figure 5.

The battery cells 130 of the example shown in Figure 5 are arranged in a rectangular array 140, as described hereinbefore with reference to the example shown in Figure 2A. Figure

5 shows only a subset of battery cells 130 in the cell group 110, for clarity. The cell group 110 of the present example comprises additional battery cells 130 arranged in the x-direction, which are not shown. In this way, the major dimension of the cell group 110 and the busbars 160a–160e comprised therein runs parallel with the x-direction. Furthermore, the banks 150a–150f, and the battery cells 130 comprised therein, are electrically connected to one another via the busbars 160a–160e in the same way as described hereinbefore with reference to Figures 2A–3B. That is, the busbars 160a–160e are connected to battery cells 130 such that an aggregate current flows in the minor dimension of the cell group 110, parallel to the y-direction.

Referring to Figure 5 in more detail, the busbars 160a–160e each comprise a spine 162, a positive connection portion 163a extending from a first side of the spine 162, and a negative connection portion 163b extending from a second, opposing side of the spine 162. The positive connection portion 163a of one busbar 160a is connected to positive terminals 133 of battery cells 130 in different rows of one bank 150a of battery cells 130, and the negative connection portion 163b is connected to negative terminals 134 of battery cells 130 in different rows of another, adjacent bank 150b of battery cells 130. In this way, the busbar 160a is configured to electrically connect the positive terminals 133 of the battery cells 130 in one bank 150a of battery cells 130 in parallel, and the negative terminals 134 of the battery cells 130 in an adjacent bank 150b of battery cells 130 in parallel, and to electrically connect the first and second banks 150a, 150b in series. The spine 162 comprises a tab 161 as described hereinbefore.

In the illustrated example, the first ends 131 of the battery cells 130 are coplanar, the positive and negative connection portions 163a, 163b of each busbar 160 are coplanar, and the spine 162 of each busbar 160 is in a plane spaced parallel to and above the connection portions 163a, 163b. In this way, the cell group 110 comprises a single layer of busbars 160 so that the connection portions 163a, 163b of each busbar 160 are coplanar with the connection portions 163a, 163b of each other busbar 160, and the spine 162 of each busbar 160 is coplanar with the spine 162 of each other busbar 160.

According to the example shown in Figure 5, the positive and negative connection portions 163a, 163b of adjacent busbars 160a–160e are mutually shaped to be spaced from and conform to one another. A gap is maintained between positive and negative connection portions 163a, 163b of adjacent busbars 160a–160e to maintain electrical isolation between the busbars 160a–160e and thereby to prevent a short-circuit.

According to the example shown in Figure 5, the positive and negative connection portions 163a, 163b of each busbar 160a–160e each comprise a respective a plurality of positive and negative lateral projections 164a, 164b arranged along the respective first and second sides of the spine 162. In this way, each positive and negative lateral projection 164a, 164b forms a resilient cantilever extending from the spine 162, for instance to facilitate connection of the lateral projections 164a, 164b to respective battery cell terminals 133, 134. The positive and negative lateral projections 164a, 164b of adjacent busbars 160b are interleaved with one another.

According to the example shown, each busbar 160a–160e comprises positive and negative lateral projections 164a, 163b of different shapes. For example, one of the busbars 160a of the example shown in Figure 5 comprises four positive lateral projections 164a, two of which are generally Y-shaped, and two of which simply extend orthogonally from the spine 162. The negative connection portions 163b of one of the busbars 160c similarly comprises negative lateral projections 164b which are of a different shape to one another, and to those of other busbars 160a–160e. The pattern of positive and negative lateral projections 164a, 164b repeats along the spines 162 of respective busbars 160a–160e. It will be understood that the shapes and patterns of the positive and negative connection portions 163a, 163b are not limited to those presented in the example of Figure 5. In other examples, the positive and negative lateral projections 164a, 164b may be of any other suitable shape and/or pattern.

According to the example shown in Figure 5, each positive lateral projection 164a comprises one or more positive contacts 165a for electrically connecting to a positive terminal 133 of a respective one or more battery cells 130, and each negative lateral projection 164b comprises a plurality of negative contacts 165b for electrically connecting to a negative terminal 134 of a respective at least one other battery cell 130. In the present example, some of the positive lateral projections 164a comprise two or more positive contacts 165a connected to positive terminals 133 of a respective two or more battery cells 130. In addition, each negative lateral projection 164b comprises at least two negative contacts 165b for connecting to negative terminals 134 of a respective at least two other battery cells 130. In the present example, as shown in Figure 5, several of the positive and negative lateral projections 164a, 164b connect to battery cells 130 in different rows, while others connect to battery cells 130 in the same row.

According to the present example, the positive contacts 165a are suitably shaped and arranged to electrically connect a corresponding positive lateral projection 164a to a respective battery cell 130. The negative contacts 165b are suitably shaped and arranged to electrically connect a corresponding negative lateral projection 164b to a respective battery cell 130. In the present example, several of the positive contacts 165a comprise circular portions when viewed in a direction orthogonal to a plane of the busbars 160a–160e, each of which conform to the shape of the positive terminals 133 of respective battery cells 130. Similarly, several of the negative contacts 165b comprise semi-annular portions when viewed in a direction orthogonal to a plane of the busbars 160a–160e, each of which conform to the shape of the negative terminals 134 of respective battery cells 130. In some examples, any number of the positive and negative contacts 165a, 165b of a busbar 160a–160e are shaped as such.

According to the example shown, each busbar 160a–160e comprises an equal number of positive contacts 165a as negative contacts 165b. That is, the busbars 160a–160e each comprise an equal number of connections, in the aggregate, on opposite sides of the spine 162. For example, each busbar 160a–160e is shown in Figure 5 as being connected to the negative terminals 134 of eight battery cells 130 on one side of the spine 132, and the positive terminals 133 of eight other battery cells 130, on the opposite side of the spine 162. In this way, current flows across the spine 162 from the positive connection portion 163a to the negative connection portion 163b.

In the present example, the connections in each busbar are evenly distributed on either side of the spine 126, so that current flow is distributed evenly along the length of each busbar 160a–160e in the x-direction, thereby reducing an amount of current flowing along the spine 126 in the x-direction. As such, an accuracy of characteristics sensed at the tab 161 at an end of each spine 162 may be improved. In other examples, the connections may be unevenly distributed on either side of the spine 162. In other examples, there may be an unequal number of connections, in the aggregate on either sides of the spine 162.

In the present example, the positive and negative contacts 165a, 165b are welded to respective battery cell terminals 133, 134 to maintain an electrical contact between the busbars 160a–160e and the underlying battery cells 130. As best seen in Figure 6, the positive contacts 165a each comprise a weld aperture 166 therethrough, through which at least a part of the weld is visible. In other examples, the negative contacts 165b may also comprise weld apertures through which at least a part of the weld is visible. In other examples, there may be no such weld apertures present on the positive or negative contacts 165a, 165b. In other examples, the positive and negative contacts 165a, 165b may be connected to respective battery cell terminals 133, 134 by any other appropriate means, such as by using a mechanical connector, an adhesive, or a magnetic fixing arrangement.

The spines 162 of respective busbars 160a–160e are each configured to bridge underlying battery cell terminals 133, 134. In other words, as best seen in Figure 6, the spine 162 of each busbar 160 is located above and spaced away from underlying battery cell terminals 133, 134, so that the spine 162 does not contact the battery cell terminals 133, 134. That is, the first ends 131 of the battery cells 130 are coplanar, the positive and negative connection portions 163a, 163b are coplanar, and are connected to the battery cells 130, and the spine 162 is in a plane spaced parallel to and above the connection portions 163a, 163b.

Furthermore, in the illustrated example, the positive and negative connection portions 163a, 163b of each busbar 160 comprise respective positive and negative bridge portions 167a, 167b, each positive and negative bridge portion 167a, 167b extending above and spaced away from underlying battery cell terminals 133, 134. That is, the first ends 131 of the battery cells 130 and the positive and negative contacts 165a, 165b are located in a first plane, and the spine 162 is located in a second plane spaced parallel to and above the first plane. The positive and negative bridge portions 167a, 167b then extend from respective positive and negative contacts 165a, 165b in first plane, towards the second plane. In some examples, the bridge portions 167a, 167b extend up to or above the second plane.

In the illustrated example, each of the negative bridge portions 167b connects a negative contact 165b of a negative lateral projection 164b to the spine 162, while some of the positive bridge portions 167a connect a positive contact 165a of a positive lateral projection 164a to the spine 162, and some of the positive bridge portions 167a form a part of the positive lateral projection 164a itself. In this way, some of the positive bridge portions 167a provide a bridge between two or more positive contacts 165a of a positive connection portion 163a. In other words, at least one positive bridge portion 167a is configured to connect the positive terminal 133 of one battery cell 130 to the positive terminal 133 of another battery cell 130 in the same bank 150 of parallel-connected battery cells 130. In other examples, one or more negative lateral projections 164b comprise negative bridge portions 167b connecting two or more negative contacts 165b of the respective negative lateral projection 164b.

The busbars 160 of the present example comprise busbar mounting apertures 169 which engage with busbar mounting projections 320 of the battery cell carrier 300, as described hereinbefore with reference to Figures 4A and 4B. This is to align the positive and negative contacts 165a, 165b of each busbar 160 with respective battery cells 130. Figure 6 shows the busbar mounting apertures 169 of a busbar 160 in more detail. In the present example, the battery cells 130 are held in the battery cell carrier by adhesive, and the busbars 160 comprise one or more adhesive insertion apertures 170 for providing access to adhesive wells of the battery cell carrier, the adhesive wells configured to distribute adhesive to battery cells 130 in the battery cell.

Figure 7 shows a part of an alternative arrangement of two busbars 160a, 160b according to an example. For ease of understanding, features of the cell group 110 which are similar to those of previous examples have been given the same reference numerals. The cell group 110 as shown in Figure 7 comprises at least one busbar 160a comprising a generally straight, elongate spine 162, and at least one other busbar 160b comprising a crooked spine 168. The straight spine 162 runs parallel with and between two adjacent rows of battery cells 130, when viewed in the z-direction. The crooked spine 168 comprises a first length 168a which runs parallel with and between a first pair of rows of battery cells 130, and a second length 168b, offset from the first length 168a, which runs parallel with and between a second pair of rows of battery cells 130. In other examples, the straight spine 162 may be aligned over a single row of battery cells 130. In other examples, the first length 168a of the crooked spine 168 may be aligned over a first row of battery cells 130, and the second length 168 of the crooked spine 168 may be offset from the first part 168a and aligned over a second row of battery cells 130, or parallel with and between a pair of rows of battery cells.

In the example shown in Figure 7, the cell group 110 comprises dummy regions 180 in the array 140 which are absent any battery cells 130. The busbars 160 are shaped to conform to the dummy regions 180, for instance so that the busbars 160 do not contact and/or do not overlie the dummy regions 180. In some examples, the cell carrier 300 comprises dummy apertures corresponding to respective dummy regions 180. In such examples, the dummy apertures may obstruct the passage of a battery cell 130 therethrough. In other examples, the dummy apertures are configured to receive adhesive. In this way, the same adhesive flow rate may be provided to each cell carrier aperture, improving an ease of manufacture of a battery module 100a–100e. In other examples, the dummy regions 180 are alternatively, or in addition, used to check a quality of a manufactured product, for instance to check whether a given quantity of adhesive is consistently provided during manufacture.

In each of the examples described hereinbefore with reference to Figures 2A–6, each cell group 110, and therefore each battery module 100a–100c, comprises at least two busbars

160 having the same form. In other examples, any number of the busbars 160 have the same form. In other examples, none of the busbars 160 have the same form.

In each of the examples described hereinbefore, the busbars 160 together cover greater than 70% of the surface area of the plurality of battery cells 130 in a cell group 110 when viewed in a direction orthogonal to a plane of the cell group 110. In other examples, the busbars 160 together cover greater than 50% or greater than 60% of the surface area of the plurality of battery cells 130 in a cell group 110.

In some examples, the battery pack 10 and/or the battery modules 100 as described hereinbefore are suitable for an electric vehicle 1. Figure 8A shows a schematic side elevation of an electric vehicle 20 comprising a battery pack 10 disposed in the electric vehicle 20. The battery pack 10 may be disposed towards a lower side of the electric vehicle 20, for instance in order to lower a centre of mass of the electric vehicle 20.

Figure 8B shows a schematic plan view of an underside of the electric vehicle 20. The electric vehicle 20 comprises a front electric drive unit 21 and a rear electric drive unit 22 for delivering power to driving wheels 23 of the electric vehicle 20. The battery pack 10 is located between the front and rear electric drive units 21, 22. In the present example, the front and rear electric drive units 21, 22 each comprise invertors for converting DC battery current into AC current to be delivered to traction motors. In other examples, the invertors are not required.

In the illustrated example, the battery pack 10 comprises an electrical connection 24 for connecting the battery pack 10 to the rear electric drive unit 22. The electrical connection 24 extends along at least one of the longitudinal passages 14, 15 of the battery pack 10. In some examples, the battery pack 10 is arranged such that a battery input/output 25 is located towards the front electric drive unit 21 of the electric vehicle and the electrical connection 24 extends from the battery input/output 25 and along a longitudinal passage 14, 15 to the rear electric drive unit 22. The electrical connection is connected to the invertor of the rear electric drive unit. In some examples, an electrical connection connecting the input/output 25 of the battery pack 10 to the front electric drive unit 21, or to a charging port of the electric vehicle 20, extends along a longitudinal passage 14, 15 of the battery pack 10.

In the present example, the battery input/output 25 is a part of the battery management system 200. In some examples, the battery input/output 25 is the controller 210. In some examples, the battery input/output 25 is located at any other location on the battery pack 10, such as towards a rear electric drive unit 22 of the electric vehicle 10.

In the example illustrated in Figure 8B, the battery pack 10 comprises eight battery modules 100, each comprising four cell groups 110. In some examples, there may be more than eight or fewer than eight battery modules 100 in a battery pack 10, and/or more than or fewer than four cell groups 110 in a battery module 100.

In the present example, the battery pack 10 is configurable to operate at either 400 volts (V) or 800 V. Operating the battery pack 10 at a particular voltage may comprise charging or delivering energy at that voltage. It will be understood that, in some examples, the battery pack 10 and the aggregate current paths or circuits comprised therein may be configured to operate at voltages other than those described. For example, a battery pack 10 configured for use in a home energy storage system or may operate at voltages lower than 400 V, while a battery pack 10 configured for industrial use may operate voltages higher than 800 V.

Although not shown in a figure, in one example, one or more busbars 160 as described in any of the above examples, for instance for use in a battery module 100, a battery pack 10 or an electric vehicle 20 according to any of the above examples, is manufactured according to a method. The method comprises: providing a sheet of conductive material, such as copper; providing at least one tool for forming the conductive material, such as a die, the tool conforming to the shape of one or more busbars 160; and stamping the one or more busbars 160 from the sheet of conductive material using the at least one tool. The method may further comprise cutting the one or more busbars 160 from the sheet of conductive material, for example using the tool, for instance after or during stamping of the one or more busbars 160.

The above examples are to be understood as illustrative examples of the invention. Further examples of the invention are envisaged. For example, a battery pack 10 or a battery module 100 may instead be used to provide and store electrical energy for any kind of industrial, commercial, or domestic purposes, such as for energy storage and delivery, for example, in smart grids, home energy storage systems, electricity load balancing and the like. A battery pack 10 may comprise any number of battery modules 100, and the cell groups 110 may comprise any number of battery cells 130.

It is to be noted that the term “or” as used herein is to be interpreted to mean “and/or”, unless expressly stated otherwise.

It is to be understood that any feature described in relation to any one example may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the examples, or any combination of any other of the examples. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.

CLAIMS

1. A battery module comprising a support, a plurality of battery cells arranged in rows on the support, and at least one busbar electrically connecting the battery cells to form a plurality of banks of parallel-connected battery cells, each bank comprising battery cells in at least two of the rows, and the at least one busbar comprising:

a spine;

a positive connection portion extending from a first side of the spine and connected to positive terminals of at least two battery cells in different rows of a first bank of parallel-connected battery cells; and

a negative connection portion extending from a second, opposing side of the spine and connected to negative terminals of at least two battery cells in different rows of a second bank of parallel-connected battery cells.

2. The battery module according to claim 1, wherein the battery module comprises at least one busbar comprising a generally straight, elongate spine, and at least one other busbar comprising a crooked spine.

3. The battery module according to claim 1 or claim 2, wherein the spine of the at least one busbar is configured to bridge underlying battery cell terminals.

4. The battery module according to any of the preceding claims, wherein each battery cell comprises a first end and a second end, wherein the first end comprises the positive and negative terminals of the battery cell and the second end is mounted to the support.

5. The battery module according to claim 4, wherein the first ends of the battery cells are coplanar, the positive and negative connection portions are coplanar and the spine is in a plane spaced parallel to and above the connection portions.

6. The battery module according to claim 4 or claim 5, wherein, for each battery cell, the positive terminal comprises one of a central projection on the first end of the battery cell and an annular portion on the first end of the battery cell, the annular portion

concentric around the central projection, and the negative terminal comprises the other of the central projection and the annular portion.

7. The battery module according to any of the preceding claims, wherein the battery module comprises a plurality of busbars and each battery cell is connected to a positive connection portion of a first busbar and a negative connection portion of a second busbar adjacent the first busbar, and wherein, for respective positive and negative connections to each battery cell, the positive connection portion of the first busbar and the negative connection portion of the second busbar are mutually shaped to be spaced from and conform to one another.

8. The battery module according to any of the preceding claims, wherein the battery module comprises a single layer of busbars, the connection portions of each busbar are coplanar with the connection portions of each other busbar, and the spine portion of each busbar is coplanar with the spine portion of each other busbar.

9. The battery module according to any of the preceding claims, wherein the positive and negative connection portions each comprise a respective one or more positive and negative lateral projections arranged along the respective first and second sides of the spine.

10. The battery module according to claim 9, wherein the at least one busbar comprises positive and negative lateral projections of different shapes.

11. The battery module according to claim 9 or claim 10, wherein the at least one busbar comprises a repeating pattern of positive and negative lateral projections along the spine.

12. The battery module according to any of claims 9 to 11, wherein the battery module comprises a plurality of busbars, and wherein positive lateral projections of a first busbar are interleaved with negative lateral projections of a second, adjacent busbar.

13. The battery module according to any of claims 9 to 12, wherein each positive lateral projection comprises at least one positive contact for electrically connecting to a positive terminal of a respective at least one battery cell, and each negative lateral projection comprises at least one negative contact for electrically connecting to a negative terminal of a respective at least one other battery cell.

14. The battery module according to claim 13, wherein the at least one positive contact comprises a circular portion and the at least one negative contact comprises a semi-annular portion when viewed in a direction orthogonal to a plane of the busbar.

15. The battery module according to claim 13 or claim 14, wherein at least one positive lateral projection comprises two or more positive contacts for connecting to positive terminals of a respective two or more battery cells, and wherein at least one negative lateral projection comprises two or more negative contacts for connecting to negative terminals of a respective two or more other battery cells.

16. The battery module according to any of claims 13 to 15, wherein the at least one busbar has an equal number of positive and negative contacts.

17. The battery module according to any of claims 13 to 16, wherein the positive and negative contacts are welded to respective battery cell terminals to maintain an electrical contact.

18. The battery module according to claim 17, wherein the positive contacts comprise an aperture through which at least a part of the weld is visible.

19. The battery module according to any of the preceding claims, wherein the positive and negative connection portions comprise respective positive and negative bridge portions, each positive and negative bridge portion extending above and spaced away from underlying battery cell terminals.

20. The battery module according to any of the preceding claims, wherein the battery module comprises at least two busbars having the same form.

21. The battery module according to any of the preceding claims, wherein the at least one busbar covers, or wherein the plurality of busbars together cover, greater than 50%, greater than 60% or greater than 70% of the surface area of the plurality of battery cells when viewed in a direction orthogonal to a plane of the battery module.

22. A battery pack comprising a battery module according to any of the preceding claims.

23. An electric vehicle comprising a battery module according to any of claims 1 to 21, or a battery pack according to claim 22.

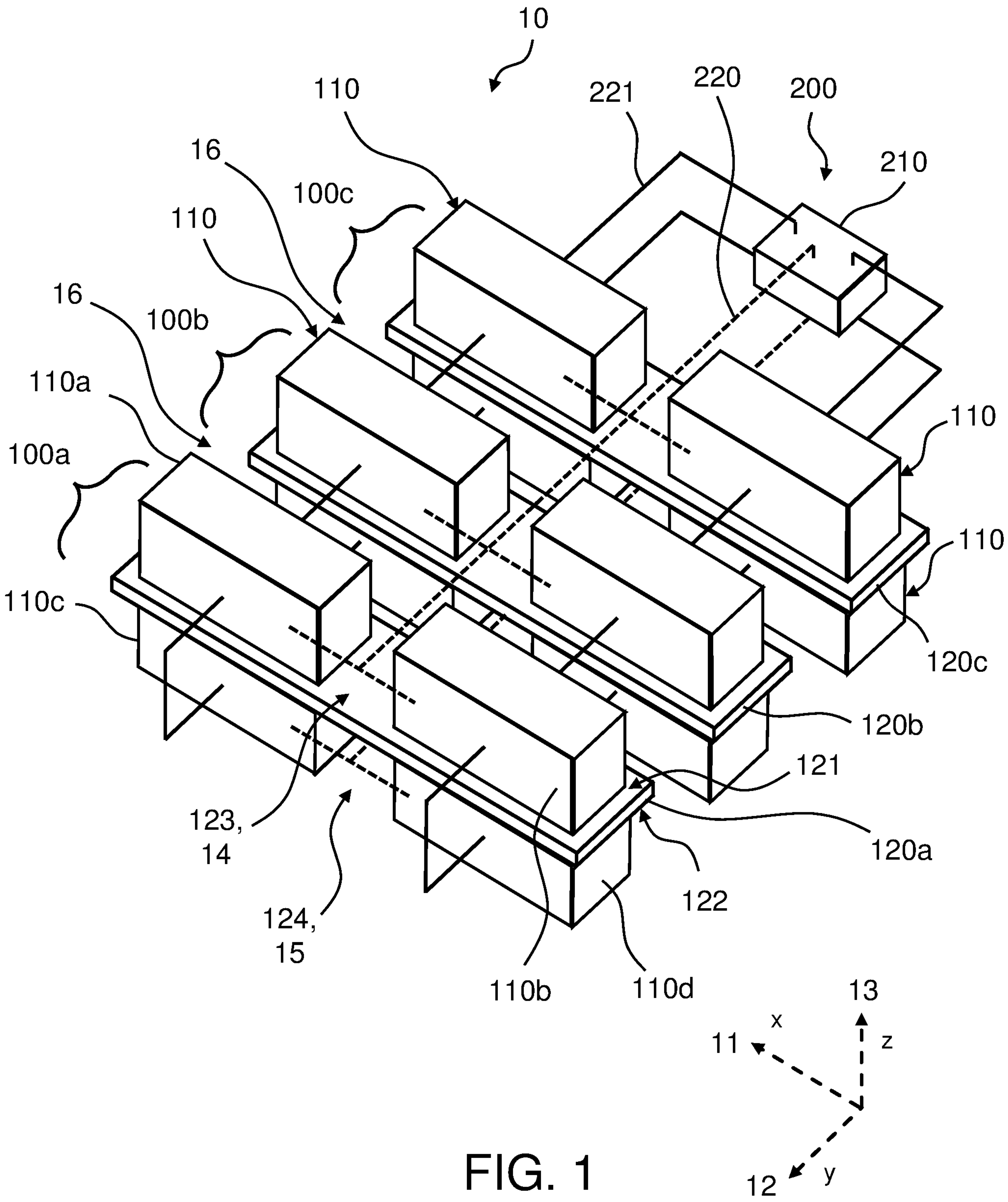
10
110
221
220
200
210
16
100c
110
16
100b
110a
100a
110
110
110c
120c
120b
121
120a
123,
14
124,
15
122
110b
110d
13
x
11
z
12
y

FIG. 1

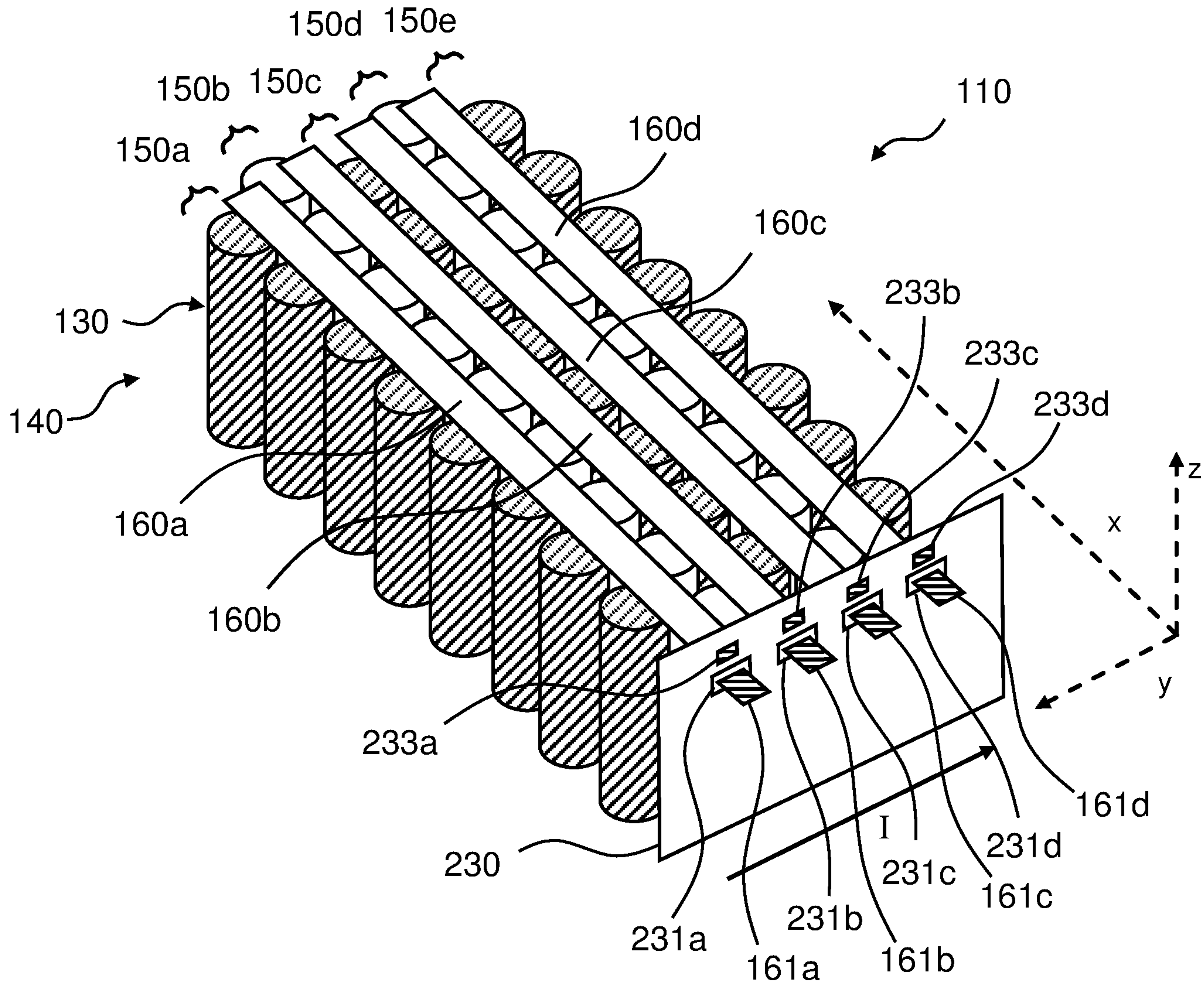
150d
150e
150b
150c
150a
110
160d
160c
233b
233c
233d
130
140
z
x
y
160a
160b
233a
161d
231d
I
231c
161c
230
231b
231a
161a
161b

FIG. 2A

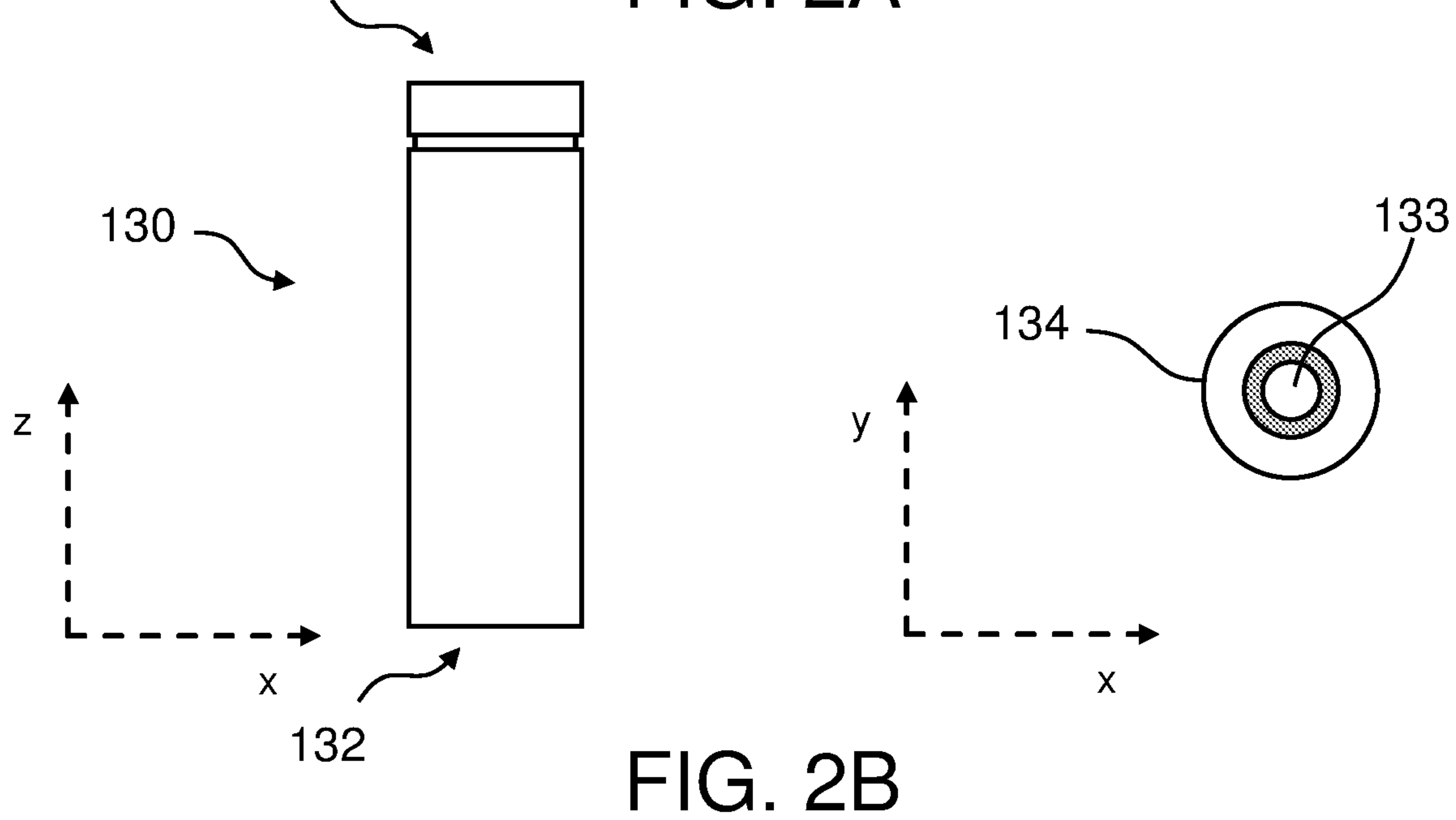
131
130
133
134
z
x
y
x
132

FIG. 2B

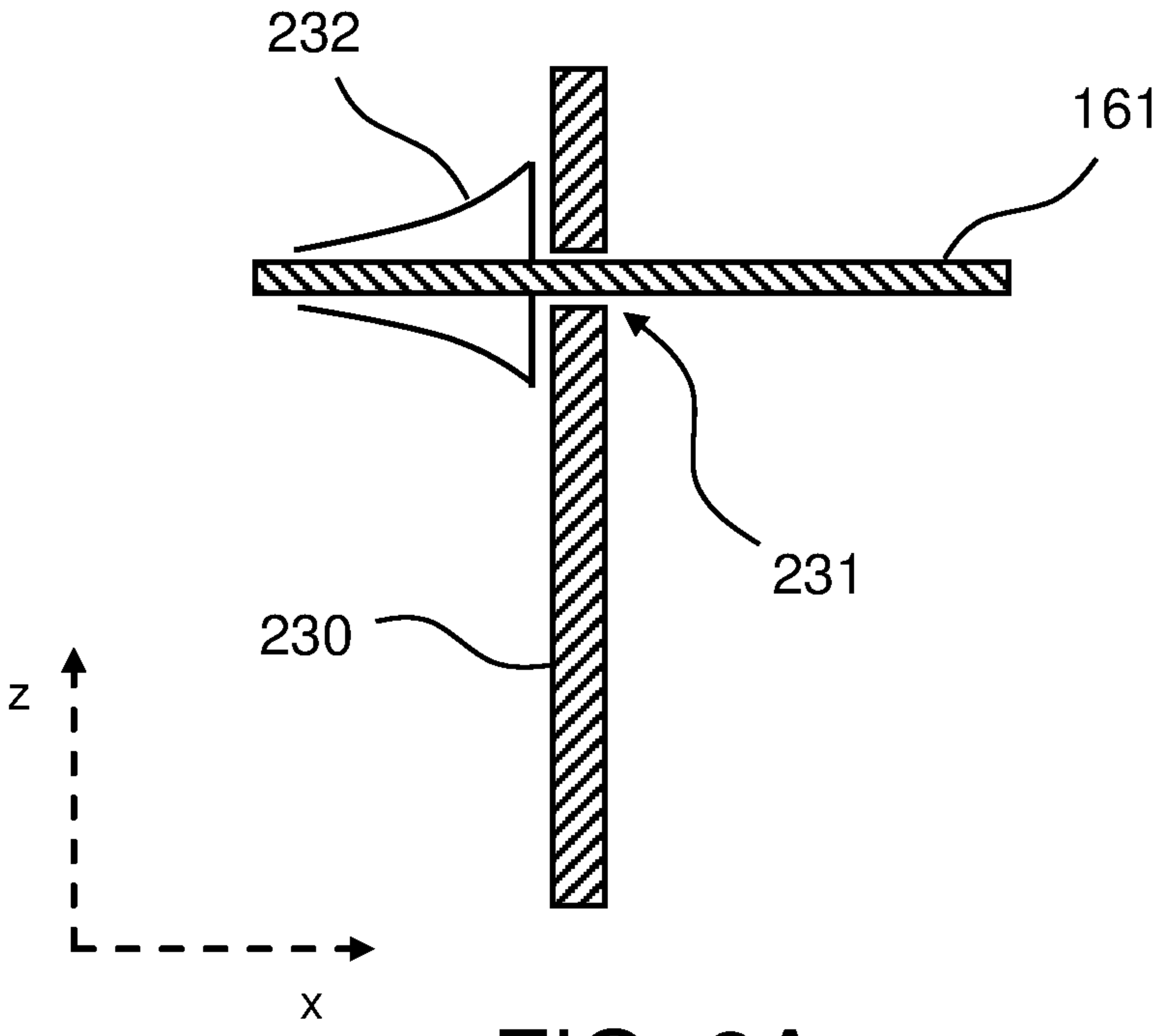

FIG. 3A

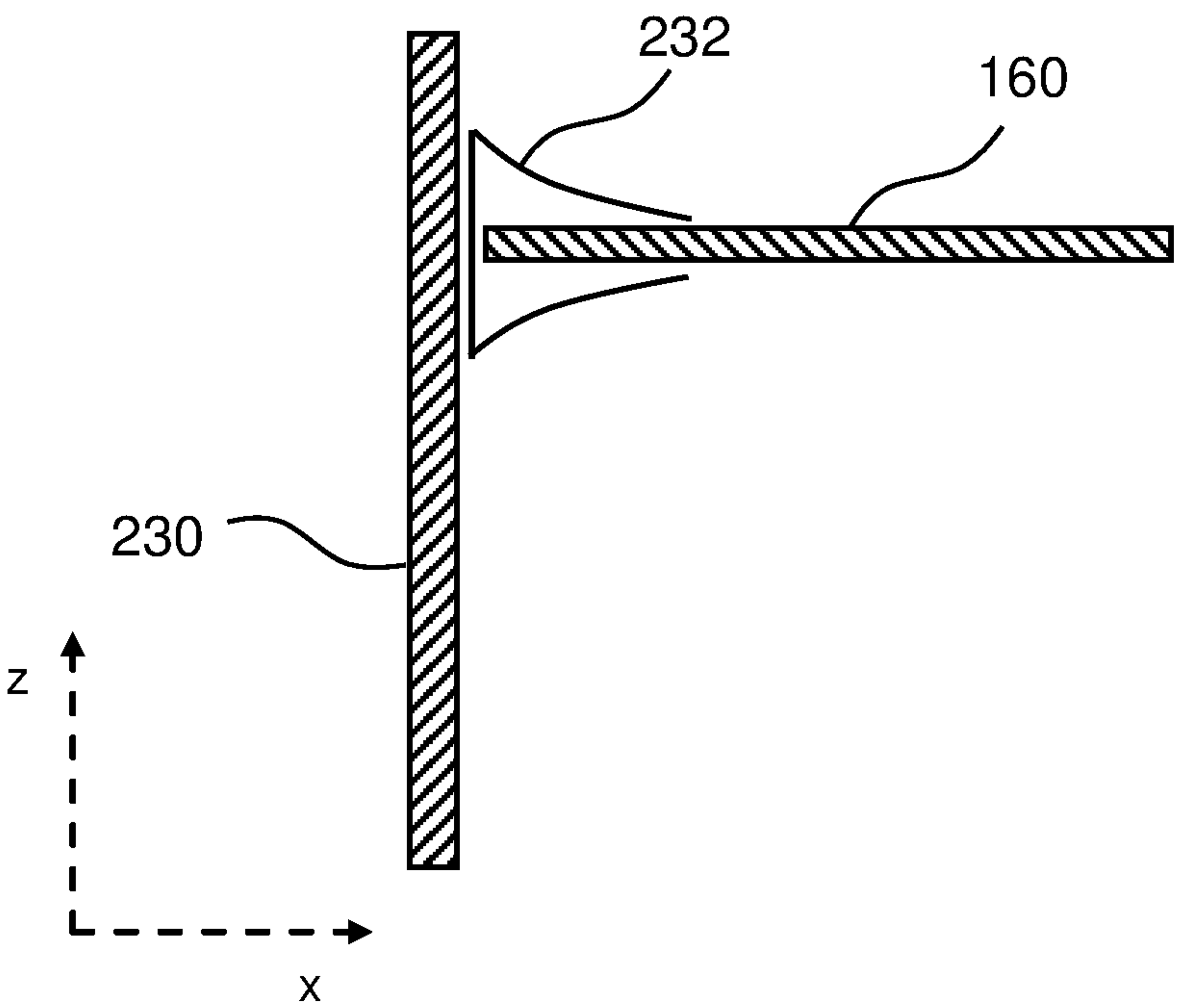

FIG. 3B

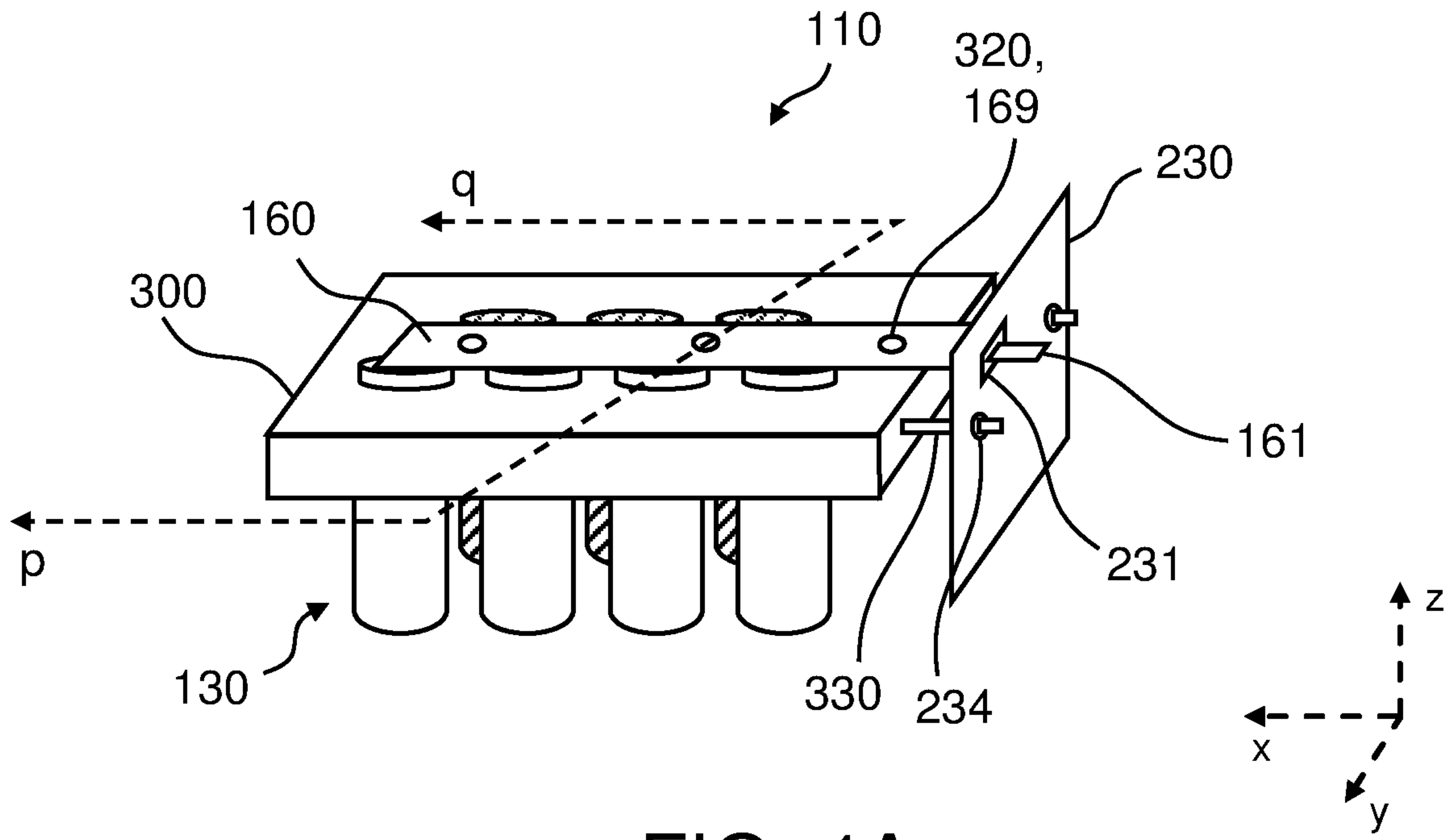
110
320,
169
230
q
160
300
161
p
231
130
330
234
z
x
y

FIG. 4A

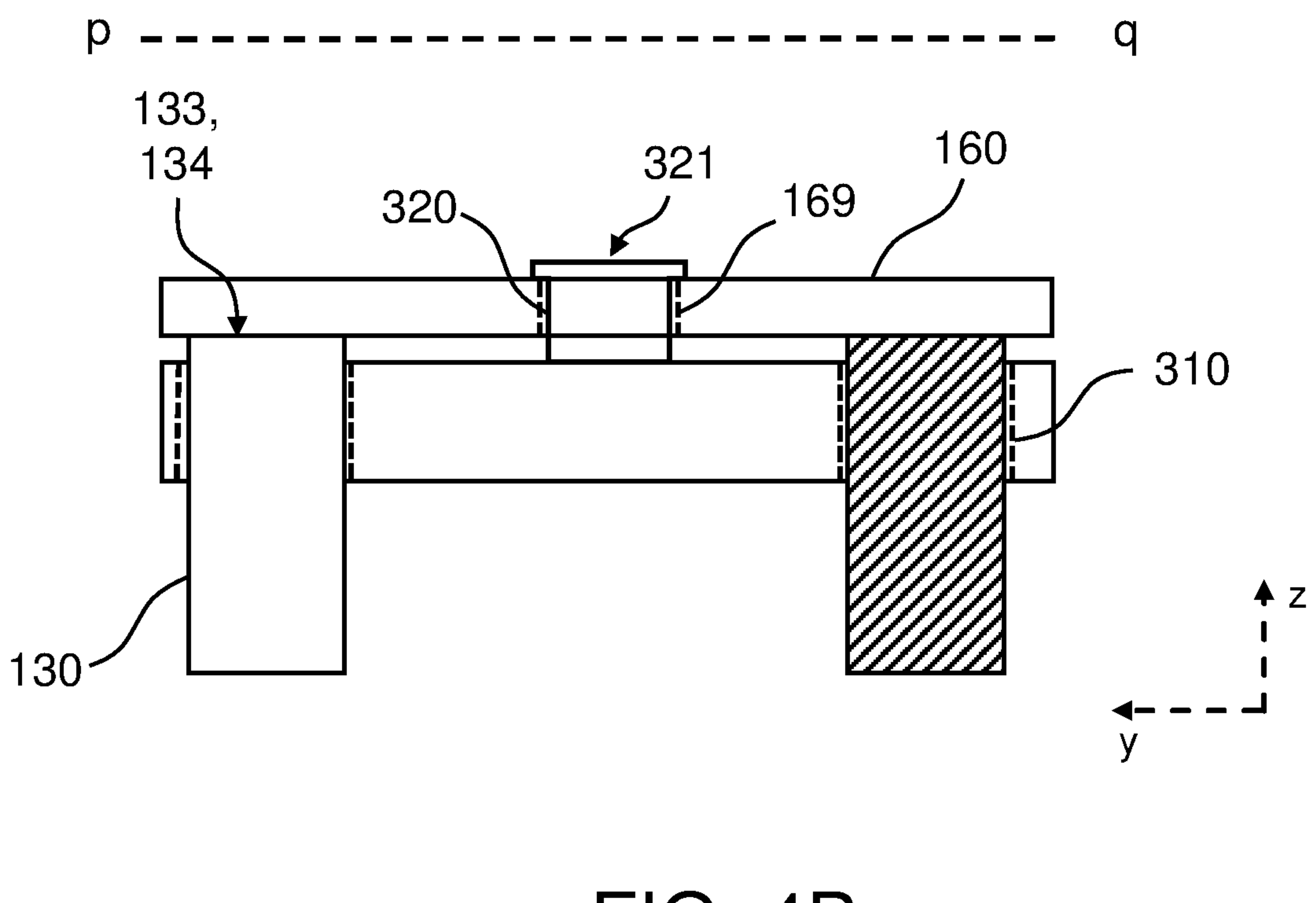
p
q
133,
134
321
160
320
169
310
130
z
y

FIG. 4B

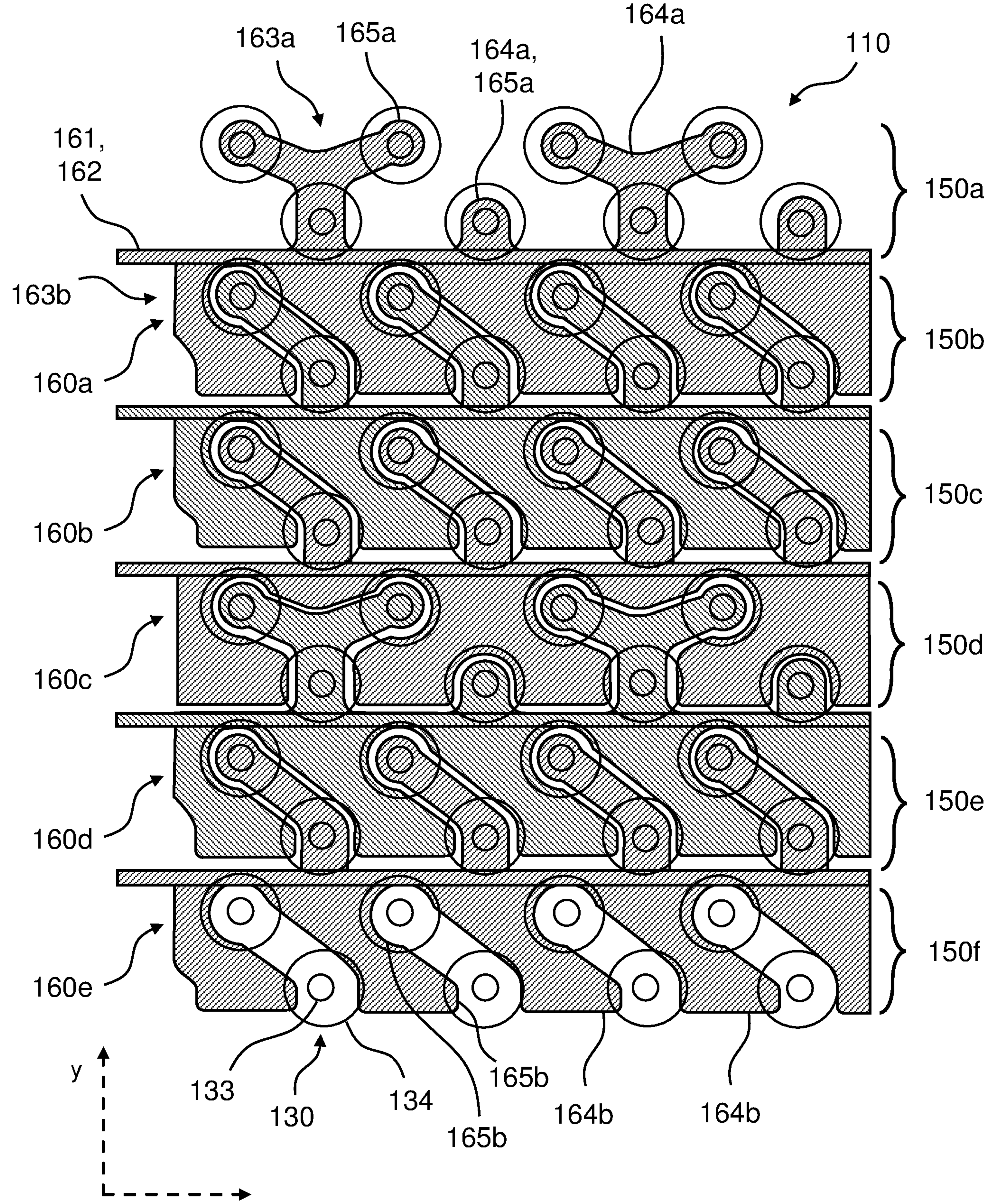
163a
165a
164a,
165a
164a
110
161,
162
150a
163b
150b
160a
150c
160b
150d
160c
150e
160d
150f
160e
y
x
133
130
134
165b
165b
164b
164b

FIG. 5

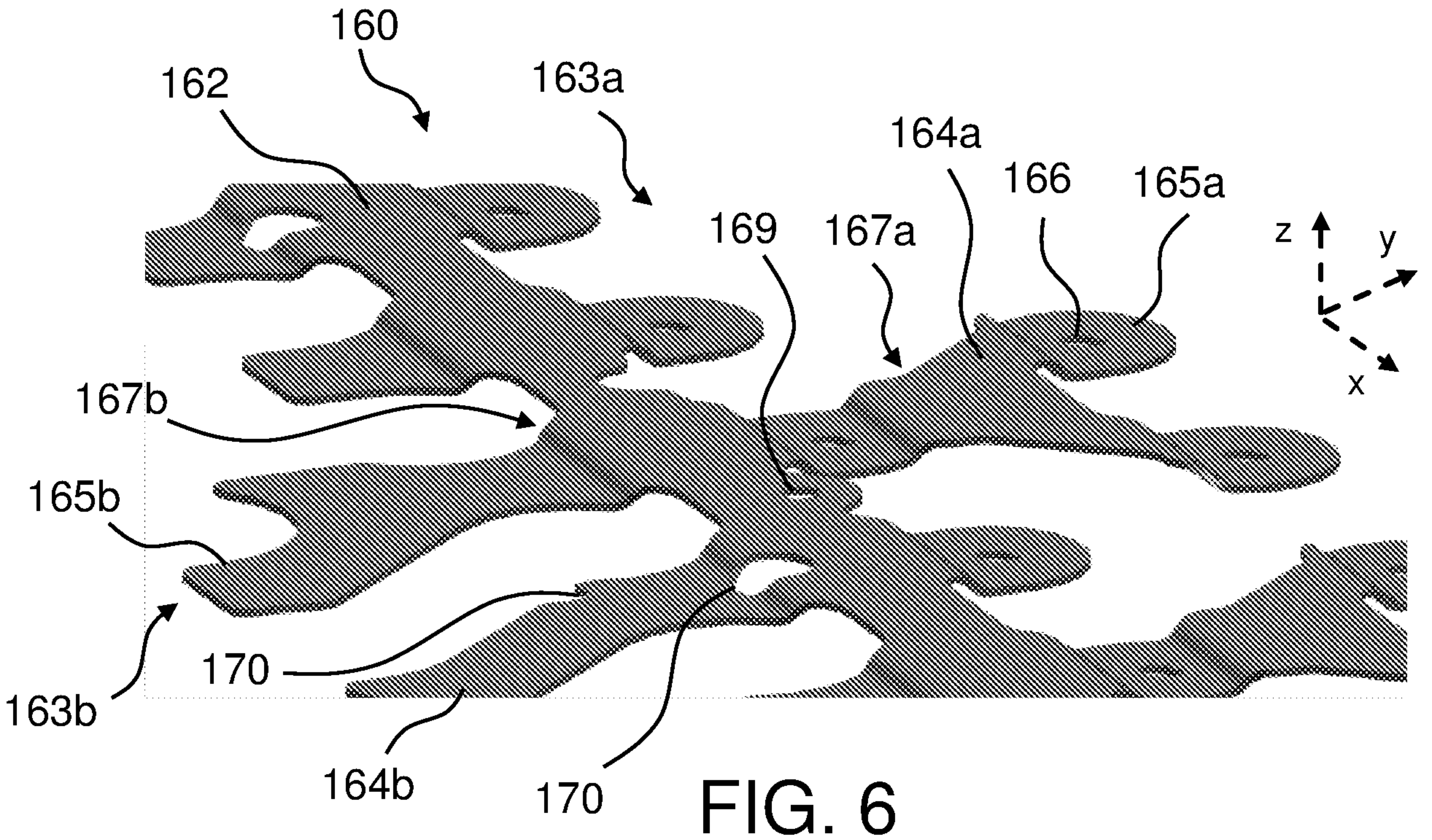
160
162
163a
164a
166
165a
169
167a
z
y
x
167b
165b
170
163b
164b
170

FIG. 6

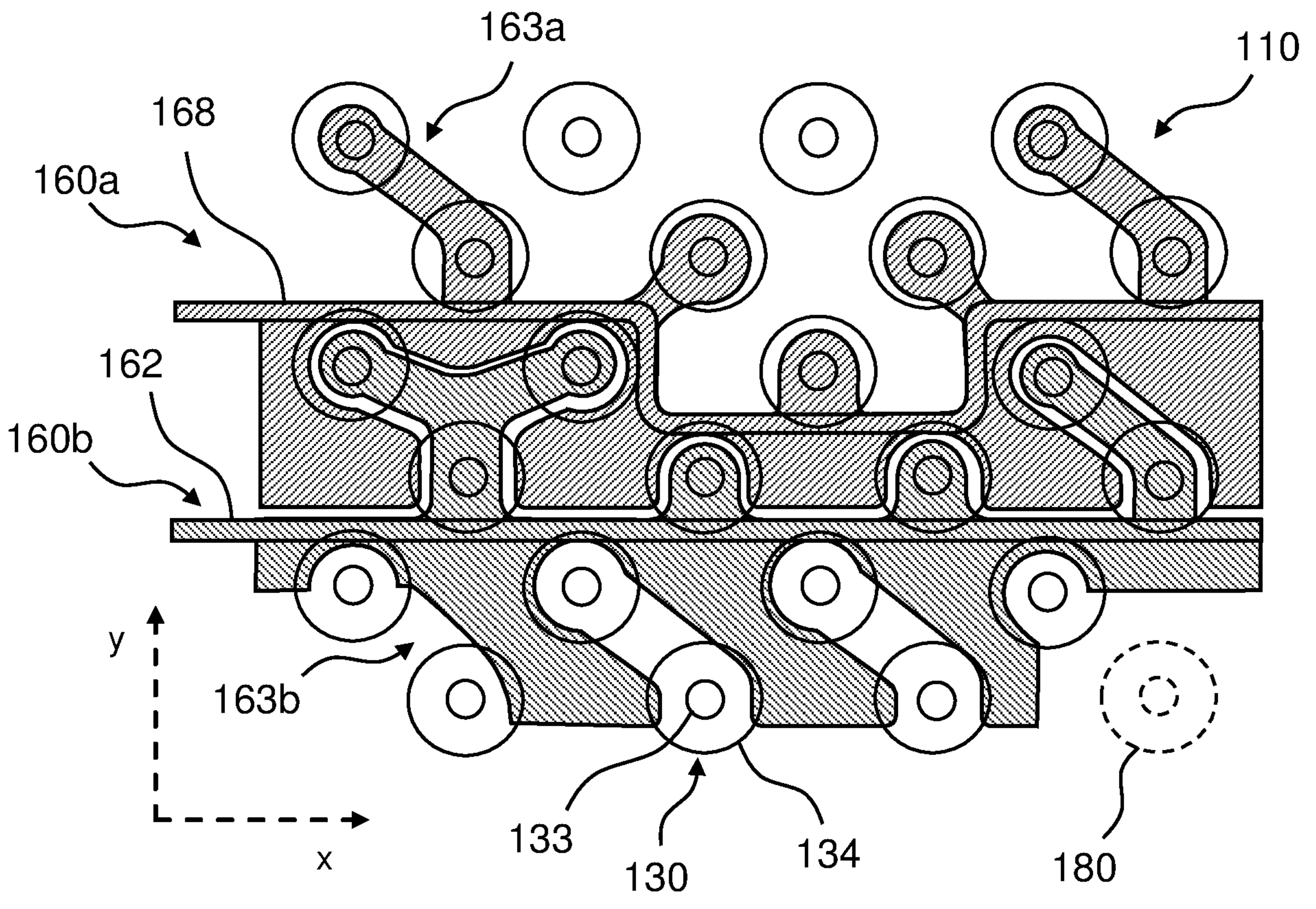
163a
110
168
160a
162
160b
y
163b
x
133
130
134
180

FIG. 7

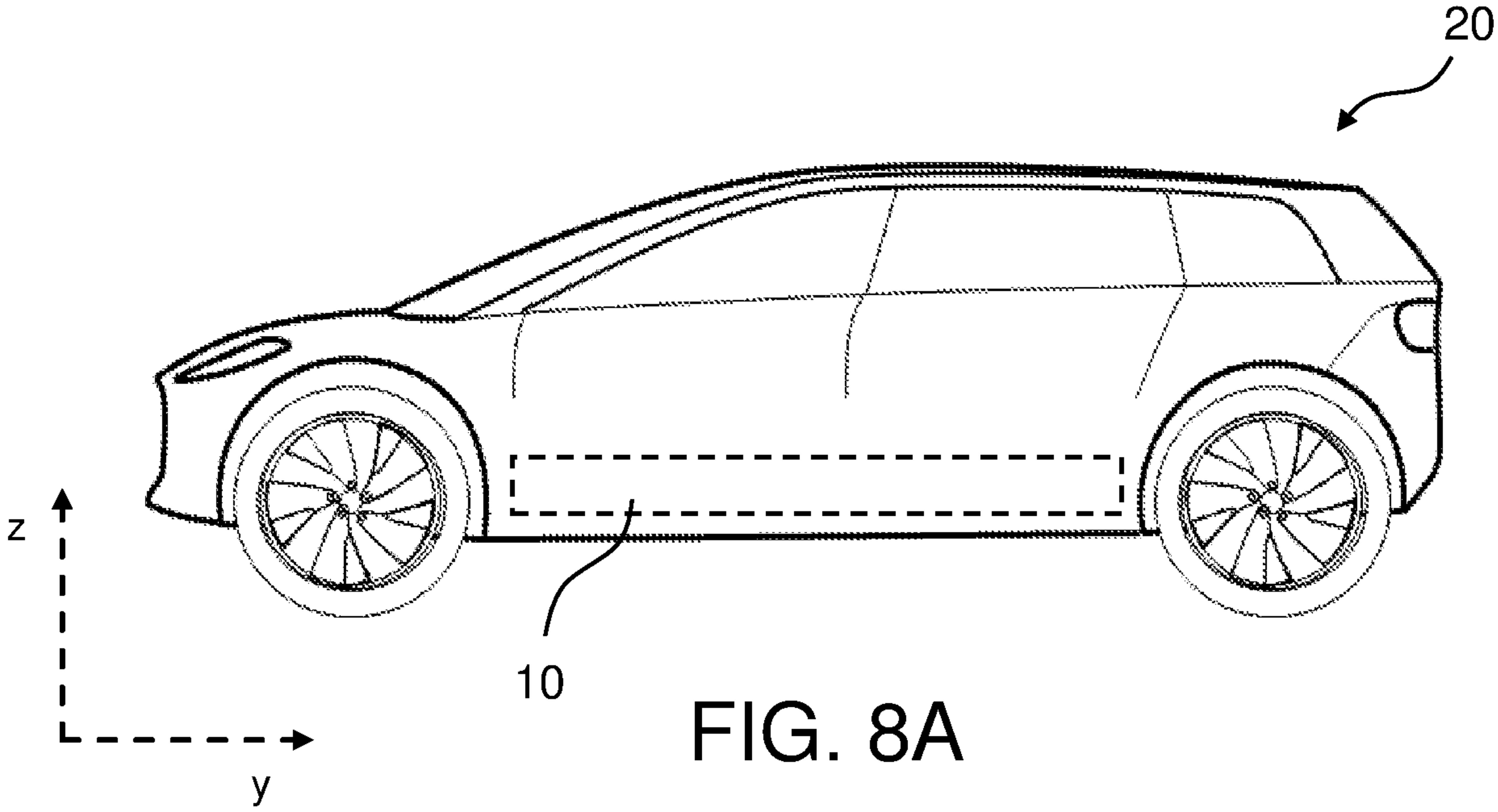

FIG. 8A

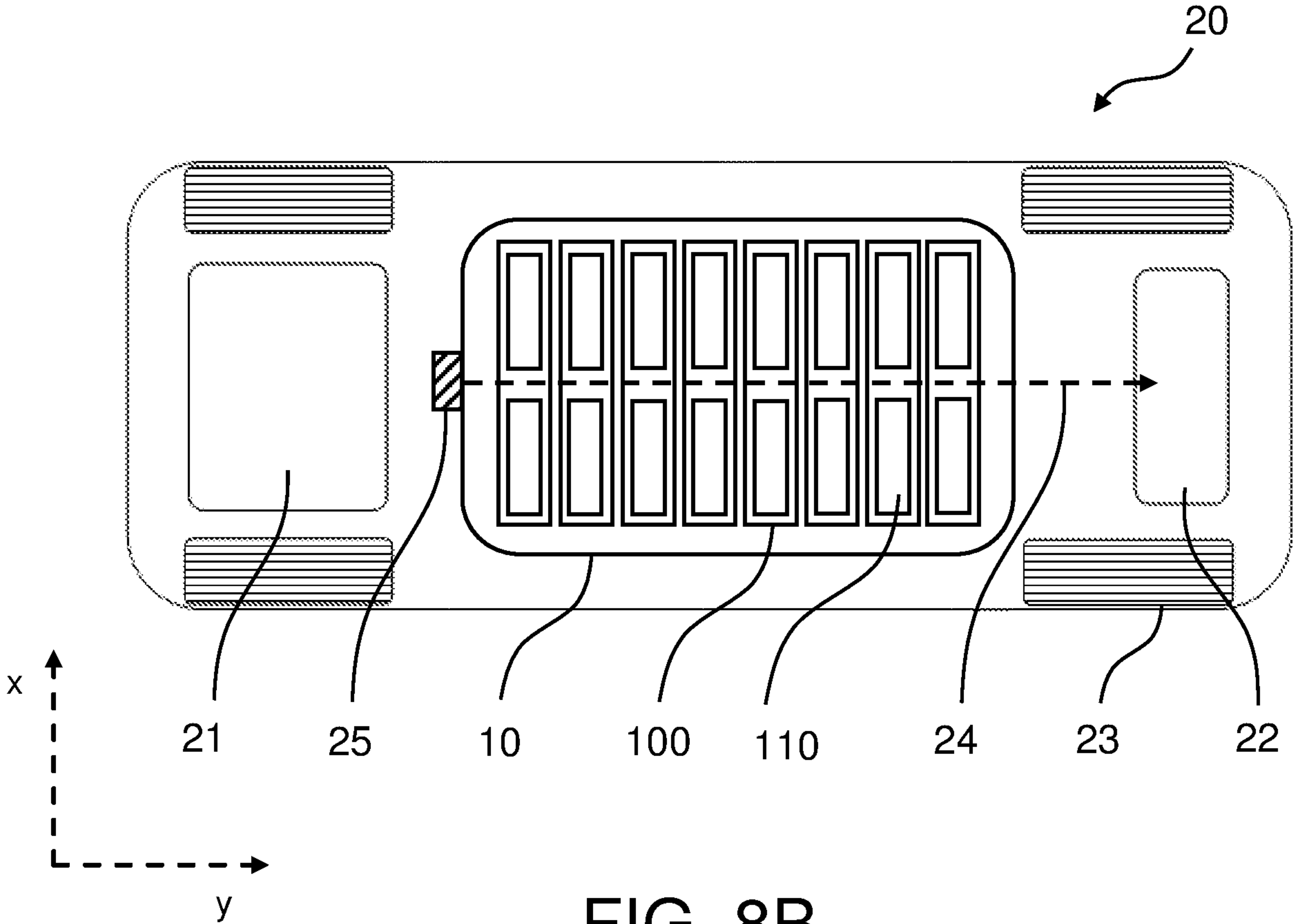

FIG. 8B

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2020/052564

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01M50/213 H01M50/503 H01M50/509 H01M2/10 H01M2/20
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2017/256769 A1 (WYNN NATHANIEL [US] ET AL) 7 September 2017 (2017-09-07) paragraphs [0001], [0042], [0054]; figures 7-16 -----	1-13, 15-23 14
Y	US 2019/296310 A1 (NEWMAN AUSTIN L [US] ET AL) 26 September 2019 (2019-09-26) paragraph [0001]; figures 4A, 4B, 12A, 12B, 13, 14 -----	14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 December 2020	13/01/2021

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hintermaier, Frank

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/GB2020/052564

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017256769 A1	07-09-2017	NONE	
US 2019296310 A1	26-09-2019	NONE	