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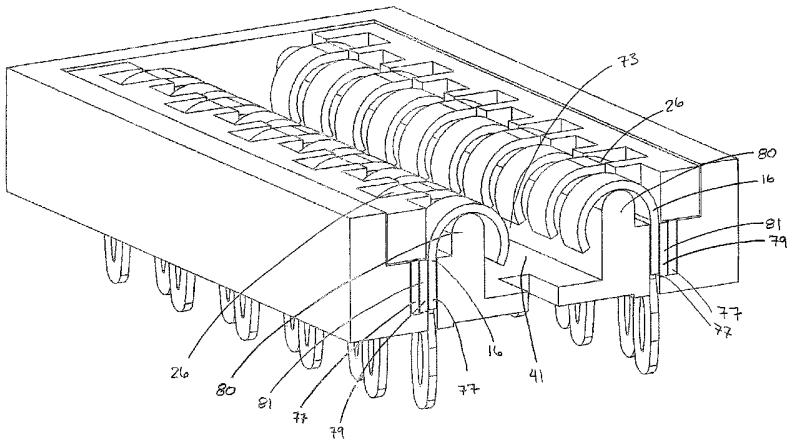


(57) Abstract: A low profile, low inductance in-line connector for providing power from a first circuit board to a second circuit board is described. The connector includes a base section that includes a housing having an interior cavity, and first and second contacts spaced apart from each other with a first insulating member positioned in a space between the contacts. The contacts each have a linear array of a plurality of mating fingers spaced apart along their lengths. The contacts are positioned in the housing such that they are essentially parallel to each other and the mating fingers of the first contact are interdigitated with the mating fingers of the second contact. The connector also includes a mating section that includes a plurality of mating contacts spaced apart from each other along a length of the mating section. The mating section fits into the interior cavity of the housing of the base section such that the mating contacts are aligned with and connect to the mating fingers of the contacts.

WO 2004/075352 A1

Power Interconnect Device

Cross-Reference to Related Applications

[0001] This application claims priority under 35 USC 119 from U.S. Provisional Application No. 60/447,532, filed February 13, 2003 under 35 USC 111(b). The disclosure of that provisional application is incorporated herein by reference. This application is also related to application Serial No. as yet unknown, attorney docket number ECN052-PCT1, entitled "Power Interconnect Device," filed contemporaneously with this application, the disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] This invention relates to power interconnect devices in general and to low inductance power distribution power interconnect devices in particular.

Introduction to the Invention

[0003] Modern electrical systems, designed with increasingly higher density circuitry packaged in smaller form factors, are driving the development of power interconnect solutions intended to deliver more power using less space. This increase in power density occurs both at the system level and at the board level, as seen in existing inter-cabinet, intra-cabinet, and PCB (printed circuit board) to PCB power distribution schemes designed to support more electrical current and power in less space. To meet these requirements, system designers can leverage custom power distribution systems that take advantage of more efficient materials and processes. For example, bus bar-based power distribution schemes and their associated power interconnect solutions are often used.

[0004] At the chip level, the power consumption and current transients of available high performance microprocessors are large and fast, respectively. Therefore, it is desired that the distribution system that supplies power to microprocessors have very low inductance and resistance to minimize voltage disturbances at the chip. A common strategy implemented to reduce inductance and resistance is to move the power source or Voltage Regulator Module (VRM) closer to the load. This method requires a separable power interconnection. Available power connectors generally require large amounts of space to have sufficiently low

inductance and resistance. Therefore, there is a need for power connectors having low inductance with reduced space requirements.

[0005] Connectors used for power distribution are commonly placed between circuit boards, many times abutting two circuit boards. The increasing need for packing more electronics into smaller volumes has led to a demand for very low profile connectors to connect circuit boards very closely together. In addition, reduced path lengths associated with very low profile connectors can result in low inductance and low resistance. Therefore the need for power connectors having low inductance with reduced space requirements specifically includes power connectors having very low profiles.

BRIEF SUMMARY OF THE INVENTION

[0006] In a first aspect, this invention provides an in-line interconnect comprising a base section and a mating section. The base section includes a housing with an interior cavity, a mounting face, a first contact having a first main body portion and a plurality of first mating fingers spaced apart along a length of the first contact, and a second contact having a second main body portion and a plurality of second mating fingers spaced apart along a length of the second contact. The contacts are positioned in the housing such that the second contact is in close proximity to but spaced apart from the first contact and is essentially parallel to the first contact, and the first mating fingers are interdigitated with, but not contacting, the second mating fingers. A first insulating member may be positioned in a space between the contacts. The mating section of the interconnect includes an insulating support member having a plurality of recesses spaced apart along a length of the support member and a plurality of mating contacts positioned in the recesses. The mating section is combined with the base section to form the interconnect by inserting the support member into the interior cavity of the housing of the base section such that the mating contacts are aligned with and contact first and second mating fingers.

[0007] In a second aspect, this invention provides a method for making an in-line connector comprising providing a base section and a mating section. The base section includes first and second contacts, wherein the first contact has a plurality of first mating fingers spaced along a length of the first contact and a plurality of terminals extending opposed from the first fingers, and the second contact comprises a plurality of second mating fingers spaced along a length of the second contact and a plurality of terminals extending opposed from the second fingers. The base section also includes a housing having an interior cavity, a mounting face, a first recess for accepting the contacts and a plurality of openings

through the mounting face. The method includes arranging the first and second contacts in the first recess to be spaced apart but in close proximity with each other and essentially parallel to each other such that first fingers are interdigitated with, but not contacting, the second fingers, and the terminals of the contacts are inserted into the openings in the mounting face of the housing. The method can include providing a first insulating member positioned between the contacts and within the first recess. The mating section includes an insulating support member having a plurality of second recesses spaced apart along a length of the support member, and a plurality of mating contacts positioned within the second recesses. The method includes positioning the mating section in the base section by inserting the support member into the interior cavity such that the mating contacts are aligned with and in electrical contact with first and second mating fingers.

[0008] In a third aspect, this invention provides an in-line connector including base section and a mating section. The base section includes a housing, a first linear array of a plurality of first contacts spaced apart longitudinally from each other along a first length of the housing and positioned in the housing, the first contacts being electrically isolated from each other, and a second linear array of a plurality of second contacts spaced apart longitudinally from each other along the first length of the housing and positioned in the housing, the second contacts being electrically isolated from each other. The first and second linear arrays are in close proximity with each but are spaced apart transversely from each other and are essentially parallel with each other. A first insulating member may be positioned between the first and second arrays. Each of the first and second contacts includes at least one mating finger. The mating fingers of the first contacts of the first linear array are interdigitated with, but not in electrical contact with, the mating fingers of the second contacts of the second linear array. The mating section of the interconnect includes an insulating support member having a plurality of recesses spaced apart along a length of the support member and a plurality of mating contacts positioned in the recesses. The mating section is combined with the base section to form the interconnect by inserting the support member into the interior cavity of the housing of the base section such that the mating contacts are aligned with and contact mating fingers of the first and second contacts.

[0009] In a fourth aspect, this invention provides an in-line connector including a base section and a mating section. The base section includes a housing, a first linear array of a plurality of first contacts electrically isolated from each other and longitudinally spaced apart from each other along a first length of the housing. The first contacts each comprise at least one mating finger. The connector also includes a contiguous contact having a second linear array of a plurality of mating fingers spaced apart along its length. The first linear array of

first contacts and the contiguous contact are positioned in the housing such that the first linear array of first contacts is in close proximity to and spaced apart from the contiguous contact, and the first linear array is essentially parallel to the contiguous contact. The mating fingers of the first contacts are interdigitated with and not electrically contacting the mating fingers of the contiguous contact. An insulating member may be positioned in a space between the linear array of first contacts and the contiguous contact. The mating section of the interconnect includes an insulating support member having a plurality of recesses spaced apart along a length of the support member and a plurality of mating contacts positioned in the recesses. The mating section is combined with the base section to form the interconnect by inserting the support member into the interior cavity of the housing of the base section such that the mating contacts are aligned with and contact mating fingers of the first contacts and mating fingers of the contiguous contact.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The drawings illustrate the design and utility of a preferred embodiment of the present invention, in which similar elements are referred to by common reference numerals. In order to better appreciate the advantages and objects of the present invention, reference should be made to the accompanying drawings that illustrate this preferred embodiment. However, the drawings depict only one embodiment of the invention, and should not be taken as limiting its scope. With this caveat, the invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

[0011] Figure 1 is an exploded perspective view of one embodiment of an interconnect of the present invention;

[0012] Figure 2 is a perspective view of one embodiment of an interconnect of the present invention;

[0013] Figure 3 is a perspective view of a base section of a connector of the present invention;

[0014] Figure 4 is a perspective view of a first contact of the present invention;

[0015] Figure 5 is a perspective view of a second contact of the present invention;

[0016] Figure 6 is a perspective view of an insert of the present invention;

[0017] Figure 7 is a perspective view showing a cross section of a base section of a connector taken along line 7-7' of Figure 3;

[0018] Figure 8 is a perspective view of a housing for a base section of a connector as viewed from the top;

[0019] Figure 9 is a perspective view of a mating section of a connector of the present invention;

[0020] Figure 10 is a perspective view of a support member for a mating section for a connector of the present invention;

[0021] Figure 11 is a cross sectional view of a connector of the present invention, taken along line 11-11' of Figure 2.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Referring to Fig. 1, the present invention provides a low profile interconnect 2 for electrically connecting two printed circuit boards (not shown). The interconnect 2 includes a base section 4 and a mating section 5. As shown in Fig. 2, when the interconnect 2 is assembled, the mating section inserts into the base section and makes electrical connection therewith. The base section 4 electrically connects to one circuit board (not shown) and the mating section 5 electrically connects to the other circuit board (not shown).

[0023] Fig. 3 shows the base section 4 without the mating section 5. The base section includes a housing 3. The housing 3 is generally rectangular having two opposed sidewalls 120, 121 parallel to a major axis A and two opposed end walls 8, 10 perpendicular to the axis A. The housing 3 also includes a mounting face 12 for mounting onto a first printed circuit board and a top face 14. The housing is made from a dielectric (insulating) material, e.g., a high temperature thermoplastic such as nylon, polyester, polyimide, PEEK, or LCP (liquid crystal polymer). The interconnect 2 also includes first contacts 16 and second contacts 26. The contacts 16 and 26 are illustrated in detail in Figures 4 and 5, respectively.

[0024] As shown in Fig. 4, the first contact 16 includes a main body portion 18 which is generally rectangular in shape. A plurality of first mating fingers 20 extend from a first edge 27 of the main body 18. The first mating fingers 20 can be uniformly spaced along the length of the contact 16. The first mating fingers 20 are integrally formed with the main body 18 and include a first curved or spring portion 22 that extends from the main body 18. The first curved portion 22 leads to a second curved end portion 24. The curved portions 22, 24 of the

first fingers together have an approximately semi-circular cross section when viewed along an axis along the main body 18. The plurality of first fingers 20 are all aligned such that if one were to view the first contact 16 from an end, one would see essentially only the first finger in the line of sight. The fingers 20 have a width X_1 and are separated along the contact 16 by a distance W_1 (measured between the edges of the fingers which are closest to each other).

[0025] Fig. 5 shows a second contact 26. The second contact has a main body 28 that is generally rectangular in shape. A plurality of second mating fingers 30 extends from a first edge 37 of the main body 28. The second mating fingers 30 can be evenly spaced along the length of the second contact. The second mating fingers 30 are integrally formed with the main body 28 and include a first curved or spring portion 32 extending from the main body 28. The first curved portion leads to straight portion 33 that is oriented approximately perpendicular to the main body. The straight portion 33 leads to a second curved end portion 34. The plurality of second fingers 30 are all aligned such that if one were to view the second contact 26 from an end, one would see essentially only the first finger in the line of sight. The second fingers 30 have a width X_2 and are separated along the contact 26 by a distance W_2 (measured between the edges of the fingers which are closest to each other).

[0026] As shown in Figs. 4 and 5, a plurality of terminals 46, 56 extend from second edges 48,58 of the main body portions 18, 28 of the contacts 16, 26, respectively. Second edges 48 and 58 of the main body portions 18 and 28 are opposed from first edges 27 and 37, respectively. In the illustrated embodiment, the terminals 46, 56 are represented as compliant contacts, specifically eye-of-the-needle throughhole posts. In this configuration, the through-hole posts are received in corresponding throughholes or vias in one of the aforementioned printed circuit boards. The vias will typically be coated with a conductive material (e.g., solder such as SnPb, Sn, Cu, Au, or Ag) and connected to conductive traces on the board. Preferably the through-hole posts are sized so that their width is slightly greater than the diameter of the vias so that a friction or press fit between the posts and the vias is achieved, creating a solderless connection. In many cases, it is desired to form such solderless connections to eliminate the requirement that electronics be exposed to high temperature of a soldering step, e.g., a reflow step in which the electronics must travel through an oven hot enough to make solder melt. However, in other cases, it may be desired to subsequently expose the interconnect 2 and board to a soldering process such as a reflow method to more securely fix the posts to the board and vias. As shown in Figures 4 and 5, the terminals may be eye-of-the-needle compliant contacts, where the compliant section of the contacts includes a hollow area; however any type of compliant contact may be used. The terminals may also be formed in a surface mount configuration for mounting on an array of conductive surface

pads that are in turn connected to corresponding circuit traces. The contacts and terminals are preferably made from a spring tempered copper alloy, for example beryllium copper. Copper alloys having high conductivity around 50% IACS (International Annealed Copper Standard) or higher are preferred for many applications. The contacts are preferably made of metal which is 0.010" (0.25mm) thick or less, for example 0.009" (0.23mm) or 0.008" (0.20mm) thick.

[0027] As shown in Fig. 3, the first and second contacts are positioned adjacent to each other and offset along their length such that the mating fingers of a first contact can be interdigitated with, but not contacting, the fingers of a second contact. The inter-finger distance W_1 for the first contact is larger than the second finger width X_2 and the inter-finger distance W_2 for the second contact is larger than the first finger width X_1 to allow the interdigitation.

[0028] Referring to Fig. 3, the interconnect 2 also includes first and second inserts 78. The inserts 78 operate to hold the contacts 16, 26 in the housing 3, and to generally align the fingers 20, 30 and separate and insulate adjacent fingers from each other. The inserts 78 are preferably made of a dielectric (insulating) material, and preferably made of the same dielectric material from which the housing is made. Examples of dielectric materials that can be used are high temperature thermoplastics such as nylon, polyester, polyimide, PEEK and LCP. Fig. 6 shows an insert 78 separately from the rest of the interconnect. The inserts 78 each have a longitudinal axis B that is parallel to the housing axis A when the inserts 78 are positioned within the housing 3. The inserts 78 include a top face 58 and a bottom face 60. The insert 78 also includes end surfaces 62, 64. Along one of the sides of the inserts 78 between the end surfaces 62, 64 is an array of slots extending between the top face 58 and bottom face 60. The slots can be evenly spaced along the length of the insert. The slots preferably alternate between deeper 66 and shallower 68 slots, relative to a direction transverse to the insert axis B. Each slot 66, 68 is separated from an adjacent slot by wall 69. The inserts are positioned within the housing 3 such that a flat side 71 of the insert abuts a sidewall 120 or 121 of the housing, where the flat side 71 of the insert is opposite the side of the insert having slots, such that the array of slots faces an interior region 73 of the housing.

[0029] Fig. 3 illustrates the base section 4 of interconnect 2 with two first contacts 16 and two second contacts 26 mounted in the housing 3 with a pair of inserts 78. A pair of one first contact 16 and one second contact 26 are mounted in close proximity to each other and approximately parallel to each other along a length of the housing 3, the contacts having their curved finger portions curving toward the interior 73 of the housing. Adjacent contact pairs

16, 26 are longitudinally offset and first fingers of the first contact are interdigitated with second fingers for the second contact. The second contact 26 is mounted to the outside of the first contact 16 (i.e., closer to the sidewall 120,121 of the housing), and therefore the curved end portions of both first and second fingers (24 and 34, respectively) extend to approximately the same depth into the interior of the housing, by virtue of the extension portion 33 of the second fingers that allows the curved end portion 34 to extend farther away from the main body 28 of the second contact. The spacing between first and second contacts is less than 0.5mm (0.020") in many cases, and in other cases, less than 0.3mm (0.012"). Inserts 78 are mounted in the housing 3 with flat sides 71 along each housing sidewall 120, 121. The slots of the inserts are positioned such that one finger of the contacts is positioned within one slot of the insert, with slot walls 69 extending between adjacent fingers to keep the fingers positioned and electrically isolated from each other. First fingers 20 can be positioned within shallow slots 68 and second fingers 30 can be positioned within deep slots 66.

[0030] Referring to Fig. 7, there is illustrated a section view of Fig. 3 along section line 7-7'. As shown in Fig. 7, the housing 3 includes a cavity 41 having a generally U-shaped cross section and longitudinal slots 77 extending along each length of the housing, the slots each being wide enough to receive the main body portion 18 of a first contact 16, an adjacent second contact 26, and to provide a space 79 therebetween. The fingers curve toward the interior 73 of the housing over walls 80 defining the one side of the slots 77. The walls 80 may have curved tops to accommodate the curvature of the contact fingers. An insulator 81 is positioned in the space 79 between the first and second contacts. The insulator 81 can be integral with the housing 3, such that the slots 77 comprise two sections separated by the insulator 81. Alternatively, the insulator 81 can be a separate element that is inserted into a slot 77.

[0031] Fig. 8 shows a view of the base section 4 of the interconnect 2, as viewed from the approximately the mounting face 12 of the base section 4. The housing 3 includes an array of holes 82 in the mounting face in the interior region 73. In addition, a plurality of openings 83 in the mounting face 12 underneath the slots 77 exist to allow terminals 46, 56 from the contacts 16, 26 to extend through the housing 3.

[0032] Fig. 9 shows a view of the mating section 5 of the interconnect 2. The mating section 5 includes an insulating support member 101 having a generally cuboid shape. The support member 101 is made of a dielectric material, preferably the same dielectric material as used for the housing 3. The mating section includes a plurality of mating contacts 103 spaced apart along a length of the support member. Fig. 10 shows the support member 101 of

the mating section 5 without the mating contacts 103. The support member 101 includes a plurality of recesses 108 having walls 110 extending from a top face 104 of the support member almost to a bottom beveled region 105 adjacent to a bottom face 109. The support member includes end pieces 106 and 107 which are approximately flush with the bottom face 109 but extend beyond the top face 104. The support member 101 also includes mounting tabs 102 extending from the bottom face 109 and stand-offs 113 extending from the top face 104. The stand-offs 113 extend beyond the top face 104 by approximately the same distance as the end pieces 106, 107. The illustrated embodiments shown in Figs. 1 and 9 show that pluralities of mating contacts can be distributed along the length of the support member on opposing long sides 114, 115. The mating contacts 103 are made of electrically conductive metal, e.g., copper, copper alloys, or plated copper, e.g., Au-plated copper. The mating contacts have terminals 116 for making electrical connection to the circuit board. The terminals can be of any configuration suitable for making electrical contact with a circuit board. For example, the terminals can comprise feet for contacting conductive pads on the circuit board. Alternatively, the terminals 116 can comprise pins for insertion into sockets, or compliant contacts for insertion into through-holes.

[0033] Fig. 2 shows the mating section 5 of the interconnect 2 inserted into the base section 4 to form an assembled interconnect 2. Fig. 11 shows a cross section of the interconnect 2 along section line 11-11' of Fig. 2. The bottom face 109 of the mating section 5 has a beveled region 105 that inserts first into the base section 4. The mating contacts 103 are spaced apart to align with and make electrical contact with the fingers 20, 30 of contacts 16, 26 in the base section 4 of the interconnect 2. Therefore the mating contacts 103 will make contact with first fingers 20 and second fingers 30 in an alternating manner. The mating section 5 is pressed into base section 4 so that the mounting tabs 102 are received into the slots 82 of the housing. When the interconnect 2 is assembled with mating section 5 fully seated in base section 4, end pieces 106, 107 and stand-offs 113 of the support member 101 extend beyond the housing 3 to the same level 125 to provide a level surface to mount to a circuit board. In embodiments where the terminals 116 of the mating contacts 103 comprise feet for contacting conductive pads on a circuit board, the bottom of the feet should be at approximately the same level 125 as the stand-offs.

[0034] Fig. 9 illustrates an embodiment of the connector in which insulating support member 101 of the mating section 5 that has side walls 114 and 115 that are straight walls with recesses to accommodate the contacts 103, resulting in a linear set of contacts 103. Because the contacts 16, 26 are transversely offset from each other in the base section housing, the mating fingers 20, 30 of the contacts 16, 26 have different lengths (i.e., contact

26 includes an extension section 33) to account for the offset in order to make electrical connection with a linear set of contacts 103 on a mating section 5. In an alternate embodiment, the side walls 114 and 115 of the support member 101 of the mating section 5 can have walls having a notched profile, such that there are alternating deep and shallow sections along the length of support member 101. A recess for accepting a contact 103 can be present in each of the deep and shallow sections, and the resulting array of contacts 103 will have an oscillating profile. In this case, the mating fingers 20, 30 of contacts 16, 26 can be the same or similar to each other and the extension section 33 may not be necessary, as the oscillating profile of the contacts 33 on the mating piece 5 can account for the offset between the contacts 16, 26.

[0035] One application of the present invention is to connect a voltage regulator module (VRM) printed circuit board to other printed circuit boards, to enable board-to-board power distribution. A specific application is to connect a VRM printed circuit board to a microprocessor printed circuit board. From an electrical performance standpoint, it is desired to keep both the resistance and the inductance of the connector in these application as low as possible to minimize voltage drop across the connector. The resistance can be minimized by choosing high conductivity materials and designing the connector to have an electrical path with short path lengths and large cross-sectional areas. Loop inductance is proportional to the magnetic field produced by the power path/return (ground) path of the configuration. Short path lengths will help to minimize loop inductance. Furthermore, magnetic field cancellation is a function of the geometry and separation of the power path and return path. The smaller the gap between power and ground, the more effective the magnetic field cancellation becomes, and the loop inductance of the connector can be minimized. The loop inductance of a connector of the present invention can be 200pH or less, compared to loop inductances of existing connectors such as card edge connectors or blade and socket connectors which are generally 2nH or greater.

[0036] It is known in the art to use coaxial interconnects to connect two printed circuit boards, as described in international application WO 01/67512 A3 and U.S. Patent Nos. 6,618,268 and 6,623,279, which are incorporated herein by reference. Referring to Figure 2B of the international application, in the configuration shown, a first or inner conductive member 105A provides a line or power path from the VRM board to the microprocessor board and a second or outer conductive member 105B provides a return or ground line from the microprocessor board to the VRM board. As such, while the coaxial geometry of this interconnect can provide low inductance, it is not a suitable approach for the efficient utilization of space, e.g., circuit board real estate.

[0037] Board real estate requirements and inter-board distance requirements can be reduced significantly with an in-line connector configuration of the present invention. In the present invention, referring to Fig. 3, for a pair of contacts including a first contact 16 and a second contact 26, one of the two contacts serves as a line or power contact and the second of the two contacts serves as a return or ground contact. The close proximity and interdigitation of the first and second contacts in the interconnect 2, and the resulting small well-controlled distance between the ground and power paths, can lead to very low loop inductance. As shown in Fig. 3, the interconnect 2 can include two power/return paths, one to each transverse side of the housing axis A. The interconnect provided herein can have a very low profile, that is the height of the interconnect as measured from the mounting face 12 of the housing to the level plane 125 of the mating section 5 can be very small, e.g., less than 4 mm, or less than 3 mm.

[0038] In an alternate embodiment, the individual contacts 16, 26 of the present invention may be separated into multiple contacts to provide additional line interconnects. More particularly, referring to Figures 4 and 5, contacts 16, 26 may be divided into two or more contacts by separating the contact at a line on the main body portion 18 or 28, for example at one or more of the dashed lines 118, 128. The multiple contacts (formed by sub-dividing the contact 16 or 26 in a manner illustrated by the dashed lines 118, 128) must each have at least one mating finger. The sub-divided contacts can be arranged in a linear array, in which the sub-divided contacts are spaced apart longitudinally and electrically isolated from each other. A first linear array of first sub-divided first contacts may be arranged in the interconnect 2 in a manner analogous to the contiguous first contact 16, and a second linear array of second sub-divided second contacts may be arranged in the interconnect 2 in a manner analogous to the contiguous second contact 26. That is, the first linear array is placed in close proximity to, but transversely spaced apart from, the second linear array, and the first linear array is essentially parallel to the second linear array. An insulating member may be positioned between the first and second linear arrays. In this manner, two, three, four or more line interconnects may be created. Each sub-divided contact may include one or more fingers 20, 30 depending upon the application requirements. In addition, the contacts 16, 26 may be scaled either up or down to include more or fewer fingers 20, 30 than in an interconnect illustrated herein. Furthermore, features from the first embodiment of the interconnect can be combined with features of the alternate embodiment to create other interconnects. For example, an individual contiguous contact 16 or 26 may be used in combination with a linear array of multiple contacts, where a contiguous contact 16 or 26 is placed in close proximity to but transversely spaced apart from a linear array of multiple contacts, with mating fingers of the contiguous contact 16 or 26 interdigitated with mating fingers of the multiple contacts in

the linear array. Interconnects of the present invention using linear arrays of multiple contacts can be easily customized, allowing the interconnects to be used in a variety of applications.

[0039] The foregoing detailed description of the invention includes passages which are chiefly or exclusively concerned with particular parts or aspects of the invention. It is to be understood that this is for clarity and convenience, that a particular feature may be relevant in more than just the passage in which it is disclosed, and that the disclosure herein includes all the appropriate combinations of information found in the different passages. Similarly, although the various figures and descriptions thereof relate to specific embodiments of the invention, it is to be understood that where a specific feature is disclosed in the context of a particular figure, such feature can also be used, to the extend appropriate, in the context of another figure, in combination with another feature, or in the invention in general.

[0040] It will be understood that the above-described arrangements of apparatus and the methods therefrom are merely illustrative of applications of the principles or this invention and many other embodiments and modifications may be made without departing from the spirit and scope of the invention as defined in the claims.

What is claimed is:

1. An in-line connector comprising:

a base section comprising:

a housing comprising an interior cavity and a mounting face;

a first contact having a first main body portion and a linear array of a plurality of first mating fingers spaced apart along a length of the first contact, the first contact positioned in the housing;

a second contact having a second main body portion and a linear array of a plurality of second mating fingers spaced apart along a length of the second contact, the second contact positioned in the housing such that the second contact is essentially parallel to and spaced apart from the first contact, and the first mating fingers are interdigitated with and not contacting the second mating fingers; and

a mating section comprising:

an insulating support member comprising a plurality of recesses spaced apart along a length of the support member; and

a plurality of mating contacts positioned in the recesses;

wherein the mating section is combined with the base section by inserting the support member into the interior cavity such that the mating contacts are aligned with and make contact to first and second mating fingers.

2. The connector of claim 1, comprising a first insulating member positioned in a space between the first contact and the second contact.

3. The connector of claim 1, wherein the in-line connector is positioned between first and second circuit boards such that the mounting face of the housing abuts the first circuit board and the mating contacts contact the second circuit board, and one of the first and second contacts provides a power path between the boards and the other of the first and second contacts provides a ground path between the boards.

4. The connector of claim 1, comprising a second insulating member having a length, a first straight side along the length, and a second side opposite the first straight side, wherein:

the second side comprises a plurality of slots spaced along the length and separated by walls, the slots extending from top to bottom surfaces of the second insulating member;

one mating finger is positioned within one slot of the second insulating member and a slot wall extends between adjacent fingers; and

the second insulating member is positioned within the housing such that the first straight side is positioned adjacent to a housing sidewall and bottom surfaces of the slot walls are positioned on top edges of the contacts.

5. The connector of claim 4, wherein the slots alternate in depth between a first depth and a second depth, and wherein the fingers of one of the contacts are only positioned in slots of the first depth and the fingers of the other contact are only positioned in slots of the second depth.

6. The connector of claim 1, wherein the first contact is spaced apart from the second contact by less than 0.5mm.

7. The connector of claim 1, wherein the contacts have a thickness of less than or equal to 0.25mm.

8. The connector of claim 1, wherein the contacts comprise a spring metal.

9. The connector of claim 8, wherein the spring metal comprises beryllium copper.

10. The connector of claim 9, wherein the beryllium copper has a conductivity of equal to or greater than 50% relative to a conductivity of copper.

11. The connector of claim 1, wherein the first mating fingers have a first curved portion integral with and extending from the first main body portion and a second curved end portion, and the second mating fingers have a first curved portion integral with and extending from the second main body portion and a second curved end portion.

12. The connector of claim 1, wherein the insulating support member has a notched profile along its length, having notched regions separated by walls, wherein recesses for accepting mating contacts are placed on both notched regions and walls such that the mating contacts are in an oscillating configuration along the length of the insulating member.

13. The connector of claim 11, wherein:

the first and second curved portions of the first fingers together comprise a semi-circular cross section when viewed along an axis of the first main body, and the end portions of the first fingers extend to a first distance in the interior cavity of the housing; and

the second fingers comprise an extension region interspersed between the first curved portion and the second end portion of the second fingers, wherein the extension region is oriented approximately perpendicular to the second main body portion and the end portions of the second fingers extend to a second distance in the interior cavity of the housing.

14. The connector of claim 13, wherein the first distance and the second distance are approximately the same when the distances are measured from a same sidewall of the housing.

15. The connector of claim 1, wherein the insulating support member has a straight profile along its length, such that the mating contacts are in a collinear configuration.

16. The connector of claim 1, wherein the contacts comprise contact terminals extending opposite the fingers, and the housing comprises openings in the mounting face through which the contact terminals extend.

17. The connector of claim 16, wherein the mating contacts comprise mating terminals for making electrical contact with conductive pads on a circuit board and the mating terminals extend from the connector opposite the contact terminals.

18. The connector of claim 2, comprising:

a third contact having a linear array of a plurality of third mating fingers spaced apart along a length of the third contact, the third contact positioned within the housing;

a fourth contact having a linear array of a plurality of fourth mating fingers spaced apart along a length of the fourth contact, the fourth contact positioned within the housing such that the fourth contact is parallel to and spaced apart from the third contact, and the third mating fingers are interdigitated with and not contacting the fourth mating fingers; and

a third insulating member positioned in a space between the third contact and the fourth contact.

19. The connector of claim 18, comprising:

a second insulating member having a first straight side along a length of the second insulating member and comprising a plurality of slots along a second side of the second insulating member opposite the first straight side thereof; and

a fourth insulating member having a first straight side along a length of the fourth insulating member and comprising a plurality of slots along a second side of the fourth insulating member opposite the first straight side thereof;

wherein:

the first and second contacts are positioned in the housing along a first length of the housing and the third and fourth contacts are positioned in the housing along a second length of the housing, the second length of the housing being opposite the first length thereof;

the fingers of the first and second contacts are positioned only in slots of the second insulating member;

the fingers of the third and fourth contacts are positioned only in slots of the fourth insulating member;

the second insulating member is positioned with its first straight side abutting a first sidewall of the housing; and

the fourth insulating member is positioned with its first straight side abutting a second sidewall of the housing opposite the first sidewall.

20. The connector of claim 19, wherein:

the slots in the second and fourth insulating members alternate in depth between a first depth and a second depth;

the fingers of one of the first and second contacts are positioned only in slots of the first depth of the second insulating member and fingers of the other of the first and second contacts are positioned only in slots of the second depth of the second insulating member; and

the fingers of one of the third and fourth contacts are positioned only in slots of the first depth of the fourth insulating member and fingers of the other of the third and fourth contacts are positioned only in slots of the second depth of the fourth insulating member.

21. The connector of claim 19, wherein:

one of the first and second contacts supplies a first power path and the other of the first and second contacts provides a ground path between a first printed circuit board and a second printed circuit board; and

one of the third and fourth contacts supplies a second power path and the other of the third and fourth contacts provides a ground path between the first printed circuit board and the second printed circuit board.

22. A method for making an in-line connector comprising:

providing a base section comprising:

first and second contacts, wherein:

the first contact has a plurality of first mating fingers spaced along a length of the first contact and a plurality of terminals extending opposed from the first fingers;

the second contact comprises a plurality of second mating fingers spaced along a length of the second contact and a plurality of terminals extending opposed from the second fingers; and

a housing comprising an interior cavity, a mounting face, a first recess for accepting the contacts and a plurality of openings through the mounting face;

arranging the first and second contacts in the first recess to be spaced apart and in close proximity with each other and essentially parallel to each other, such that the first fingers are interdigitated with and not contacting the second fingers and such that the terminals of the contacts are inserted into the openings;

providing a mating section comprising:

an insulating support member comprising a plurality of second recesses spaced apart along a length of the support member; and

a plurality of mating contacts positioned within the second recesses; and

positioning the mating section in the base section by inserting the support member into the interior cavity such that the mating contacts align with and make electrical contact to the first and second mating fingers.

23. The method of claim 22, comprising providing a first insulating member positioned between the first and second contacts and within the first recess.

24. The method of claim 22, comprising:

providing a second insulating member having a length and first straight side along the length, and a second side opposite the first side, the second side comprising a plurality of slots separated by walls spaced along the length of the second insulating member, wherein the slots extend between top and bottom surfaces of the second insulating member; and

positioning the second insulating member within the housing such that the first straight side abuts a sidewall of the housing and one mating finger is positioned in one slot of the second insulating member, and a slot wall extends between adjacent fingers.

25. The method of claim 24, wherein the slots alternate in depth between a first depth and a second depth, and wherein the fingers of one of the contacts are positioned only in slots of the first depth and the fingers of the other contact are positioned only in slots of the second depth.

26. An in-line connector comprising:

a base section comprising:

a housing;

a first linear array of a plurality of first contacts spaced apart longitudinally from each other along a length of the housing, electrically isolated from each other, and positioned in the housing;

a second linear array of a plurality of second contacts spaced apart longitudinally from each other along a length of the housing, electrically isolated from each other, and positioned in the housing, the second linear array being in close proximity to and spaced apart transversely from the first linear array and the second array being essentially parallel to the first array;

wherein each first contact comprises at least one first mating finger and each second contact comprises at least one second mating finger and the first mating fingers are interdigitated with and not contacting the second mating fingers; and

a mating section comprising:

an insulating support member comprising a plurality of recesses spaced apart along a length of the support member; and

a plurality of mating contacts positioned within the recesses;

wherein the support member fits into the interior cavity such that the mating contacts align with and are in electrical contact with first and second mating fingers.

27. The connector of claim 26, comprising a first insulating member positioned between the first array and the second array.

28. The connector of claim 26, comprising a second insulating member having a length, a first straight side along the length of the second insulating member, and a second side opposite the first side, wherein:

the second side comprises a plurality of slots separated by walls, the slots spaced along the length and extending from top to bottom surfaces of the second insulating member;

one mating finger is positioned within one slot of the second insulating member and a wall extends between adjacent mating fingers; and

the second insulating member is positioned within the housing such that the first straight side is positioned adjacent to a sidewall of the housing and bottom surfaces of the slot walls are positioned on top edges of the contacts.

29. The connector of claim 28, wherein the slots alternate in depth between a first depth and a second depth, and wherein the mating fingers of one of the linear arrays of a plurality of contacts are only positioned in slots of the first depth and the mating fingers of the other linear array of a plurality of contacts are only positioned in slots of the second depth.

30. The connector of claim 26, wherein the first mating fingers have a first curved portion integral with and extending from first main body portions of first contacts and a second curved end portion, and the second mating fingers have a first curved portion integral with and extending from second main body portions of second contacts and a second curved end portion.

31. The connector of claim 26, wherein the insulating support member has a notched profile along its length, the support member having notched regions separated by walls, wherein recesses for accepting mating contacts and mating contacts are positioned on notched regions and on walls such that the mating contacts are in an oscillating configuration along the length of the insulating member.

32. The connector of claim 26, wherein:

the first and second curved portions of the first mating fingers together comprise a semi-circular cross section when viewed along an axis of the first main body;

the end portions of the first fingers extend to a first distance in the interior cavity of the housing;

the second fingers comprise an extension region interspersed between the first curved portion and the second curved end portion of the second fingers, wherein the extension region is oriented approximately perpendicular to the second main body portions and the end portions of the second fingers extend to a second distance in the interior cavity of the housing.

33. The connector of claim 32, wherein the first distance and the second distance are approximately the same when the distances are measured from a same sidewall of the housing.

34. The connector of claim 26, wherein the insulating support member has a generally straight profile along its length, such that the mating contacts are in a collinear configuration.

35. The connector of claim 26, wherein each of the plurality of first contacts provides a separate power path between two circuit boards, and each of the plurality of second contacts provides a ground path between the circuit boards.

36. An in-line connector comprising:

a base section comprising:

a housing;

a first linear array of a plurality of first contacts, wherein the first contacts are spaced apart longitudinally from each other along a length of the housing, electrically isolated from each other, and positioned in the housing; and

a contiguous contact positioned in the housing coomprsing a second linear array of a plurality of mating fingers;

wherein:

the contiguous contact is in close proximity to and spaced apart from the first linear array of first contacts and is essentially parallel to the first linear array;

each contact of the first linear array comprises at least one mating finger; and

the mating fingers of the first contacts of the first linear array are interdigitated with and not contacting the mating fingers of the contiguous contact; and

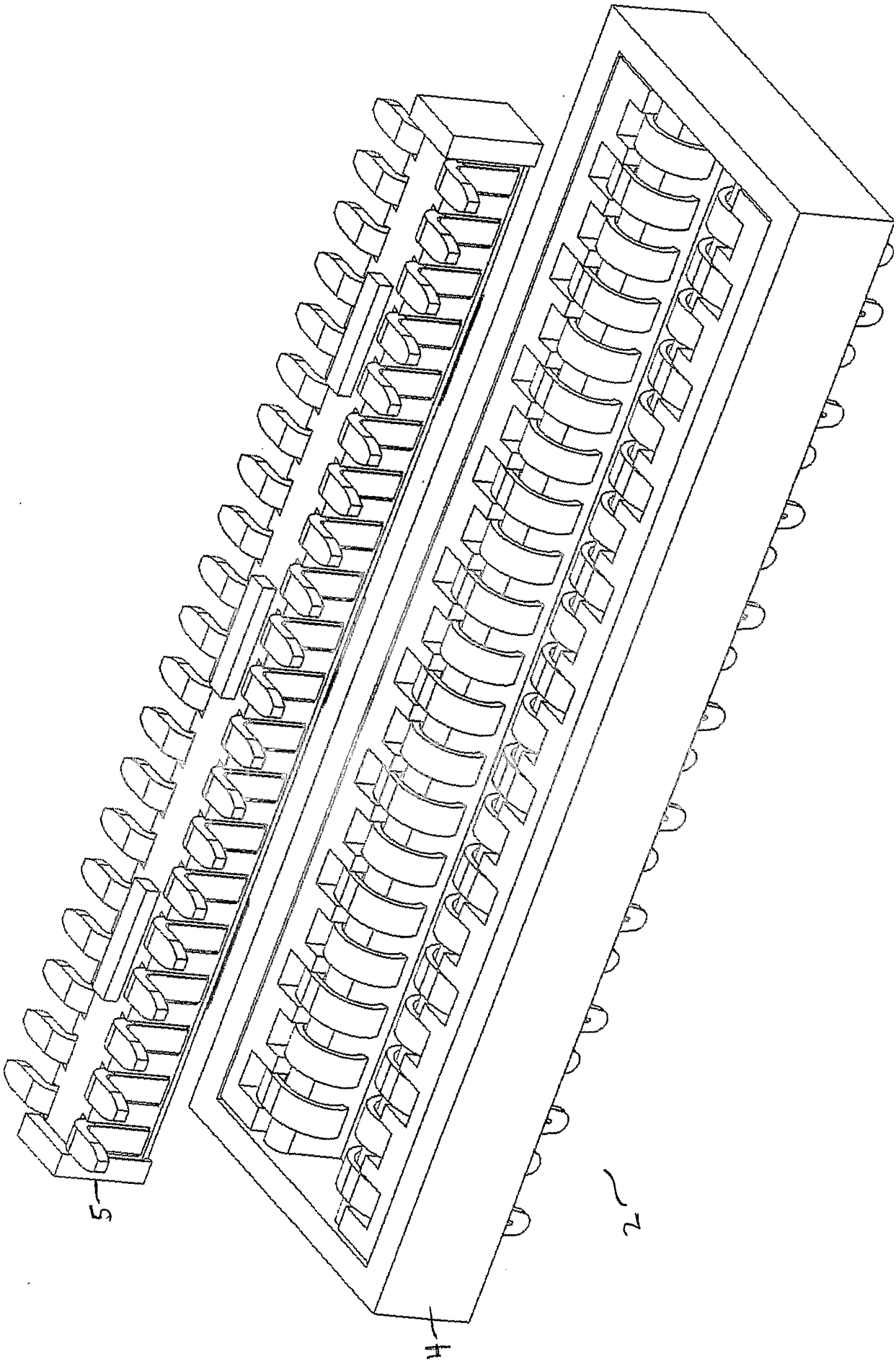
a mating section comprising:

an insulating support member comprising a plurality of recesses spaced apart along a length of the support member; and

a plurality of mating contacts positioned within the recesses;

wherein the support member fits into the interior cavity such that the mating contacts align with and are in electrical contact with mating fingers of the first linear array of first contacts and mating fingers of the contiguous contact.

37. The connector of claim 36, wherein an insulating member is positioned between the first linear array of a plurality of first contacts and the contiguous contact.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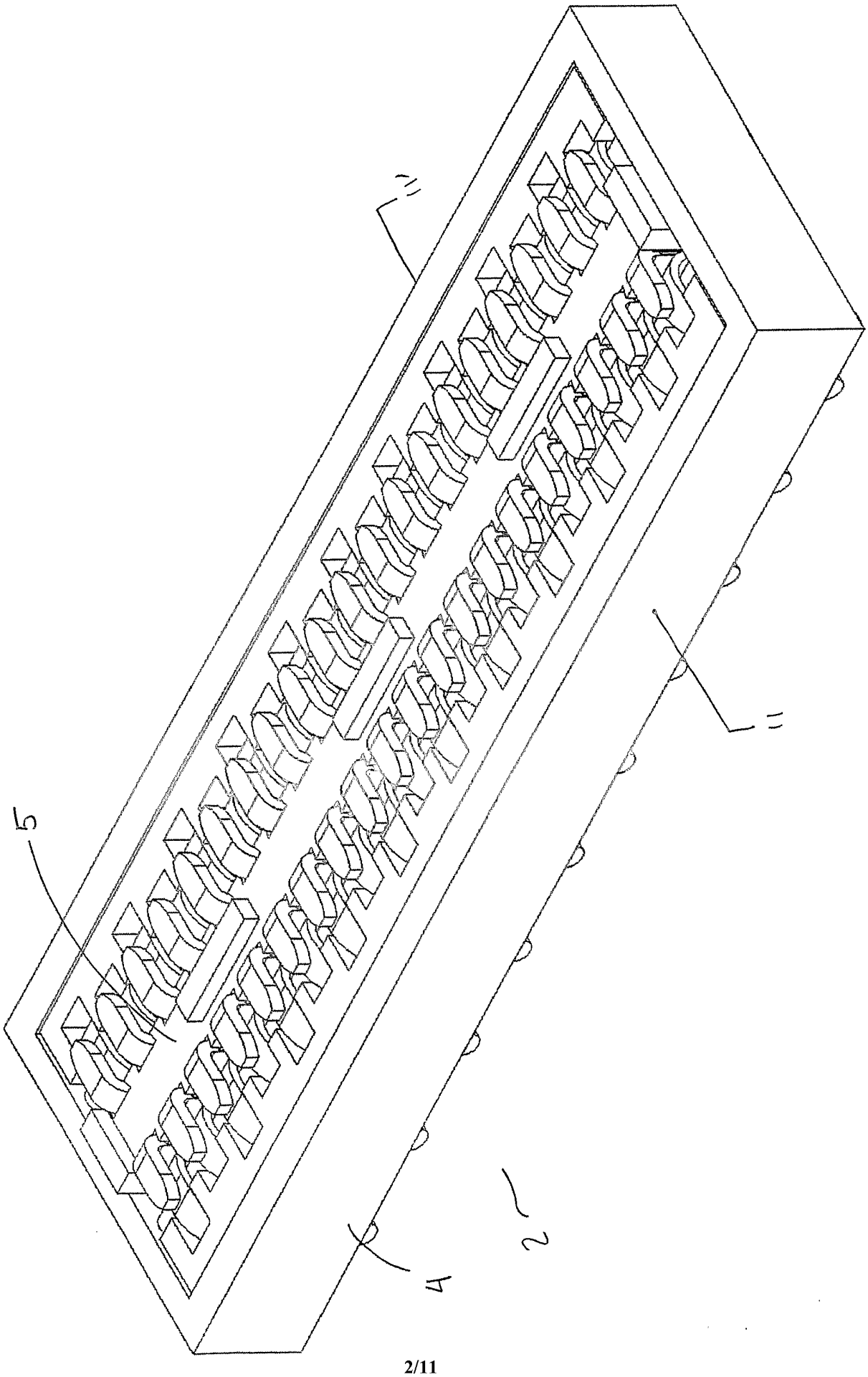
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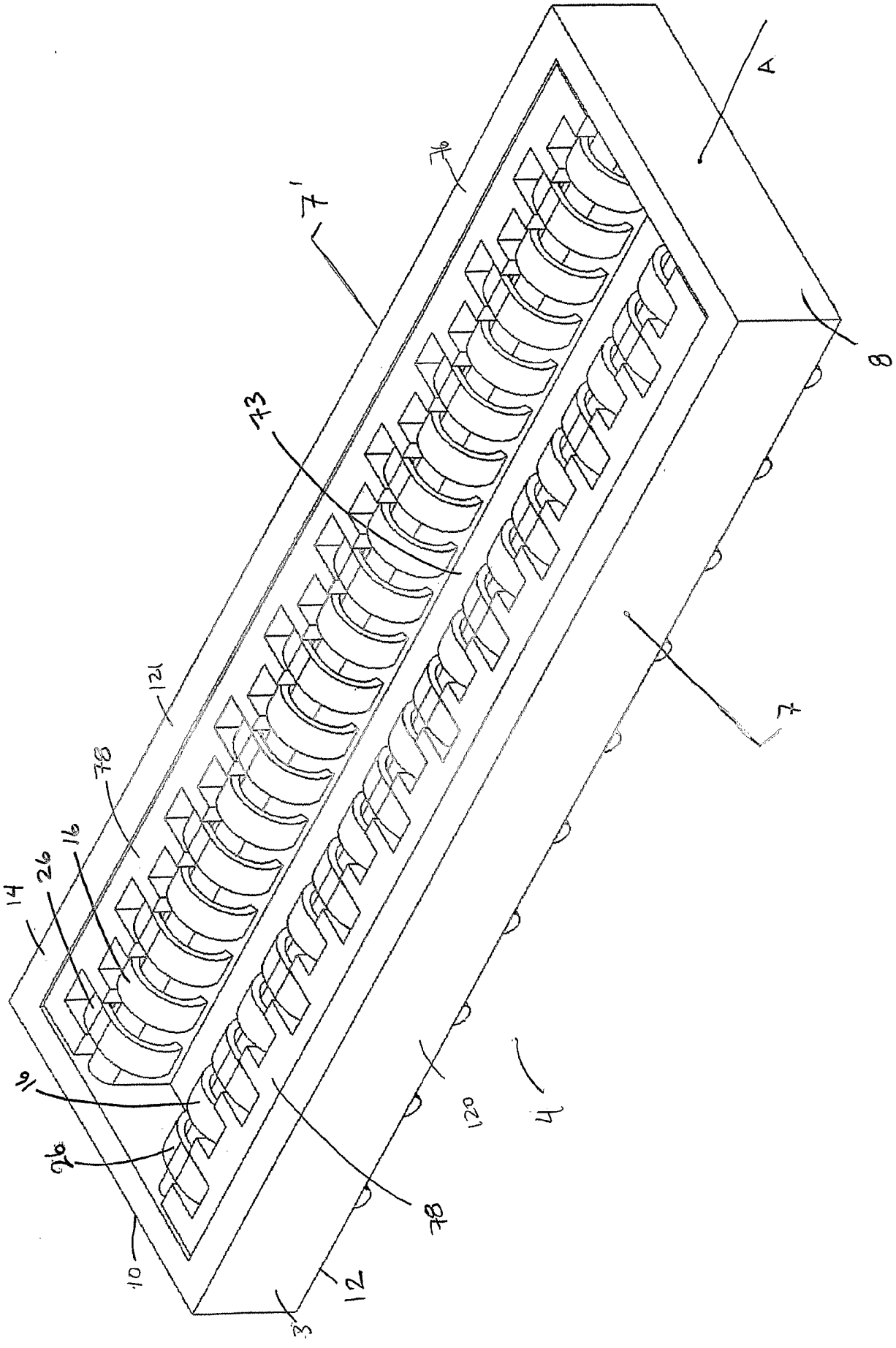
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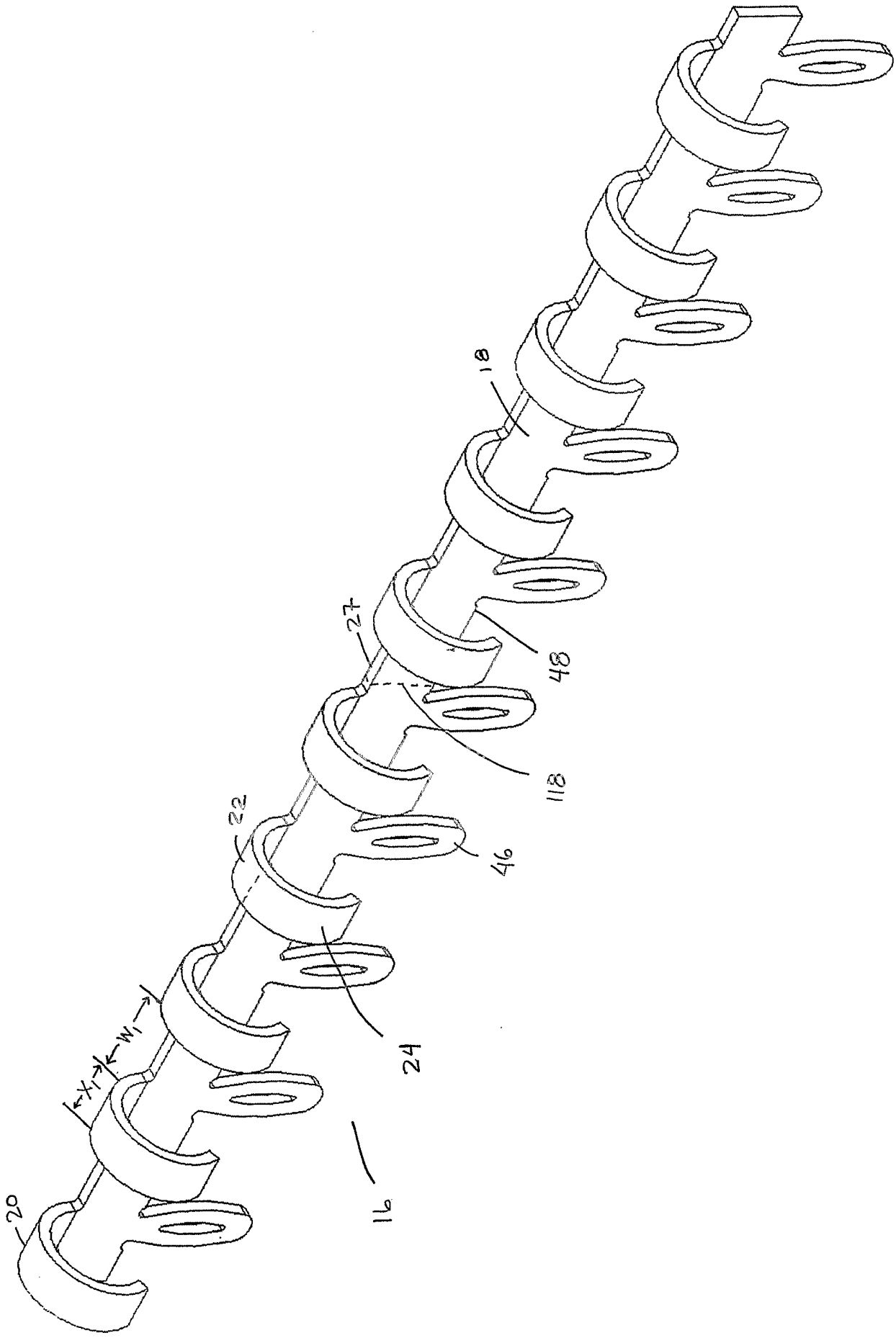
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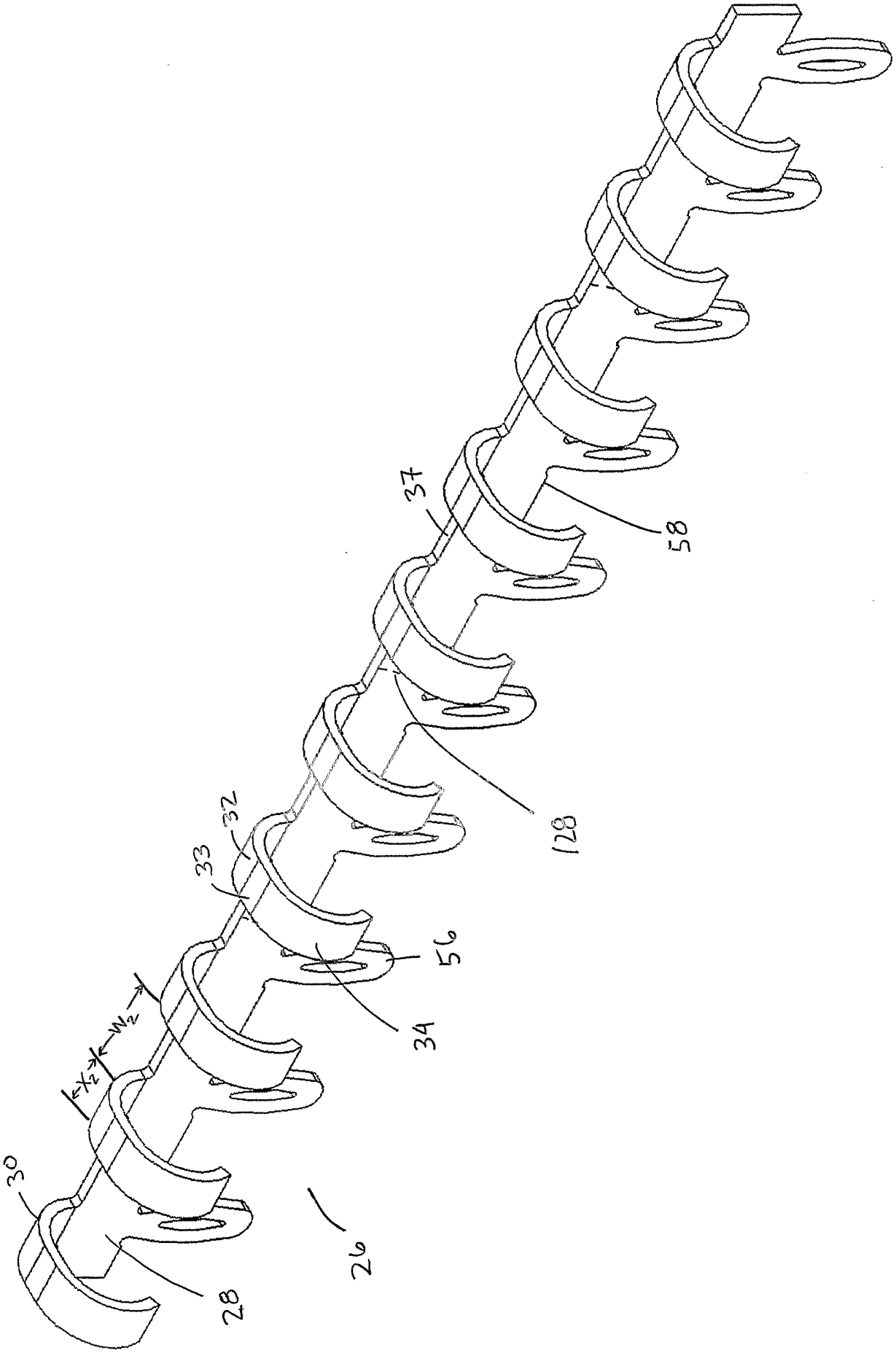
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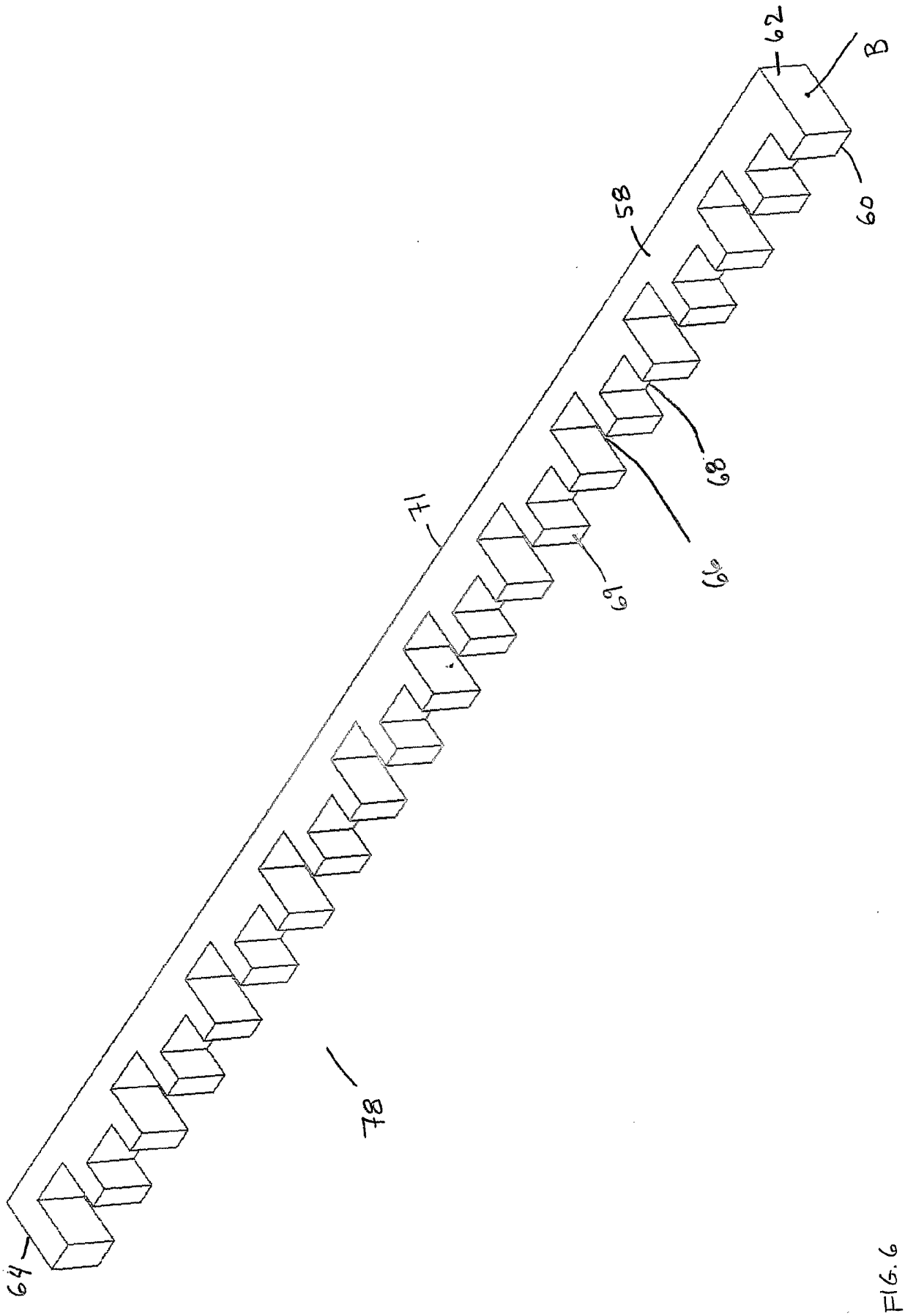
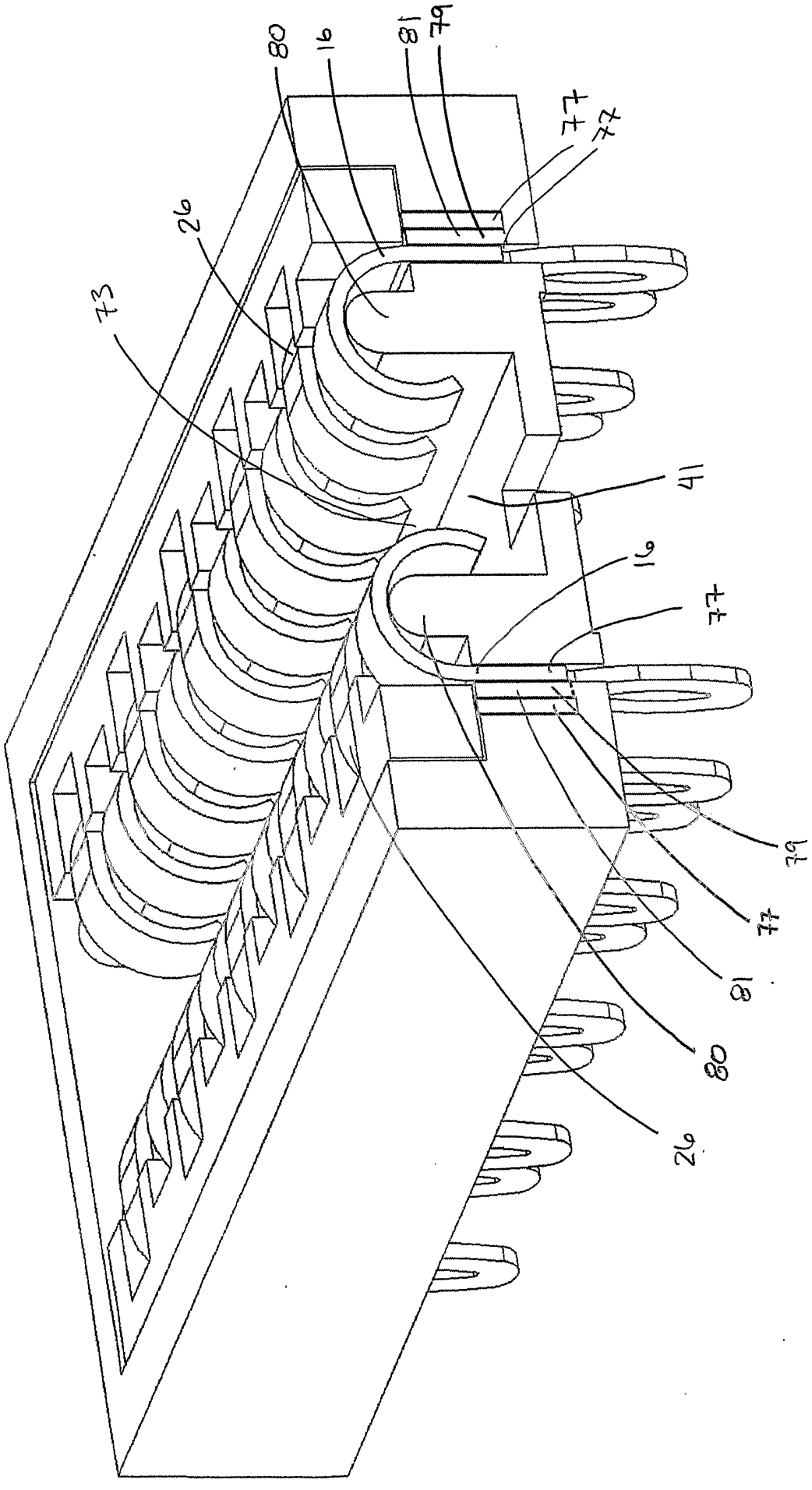


FIG. 6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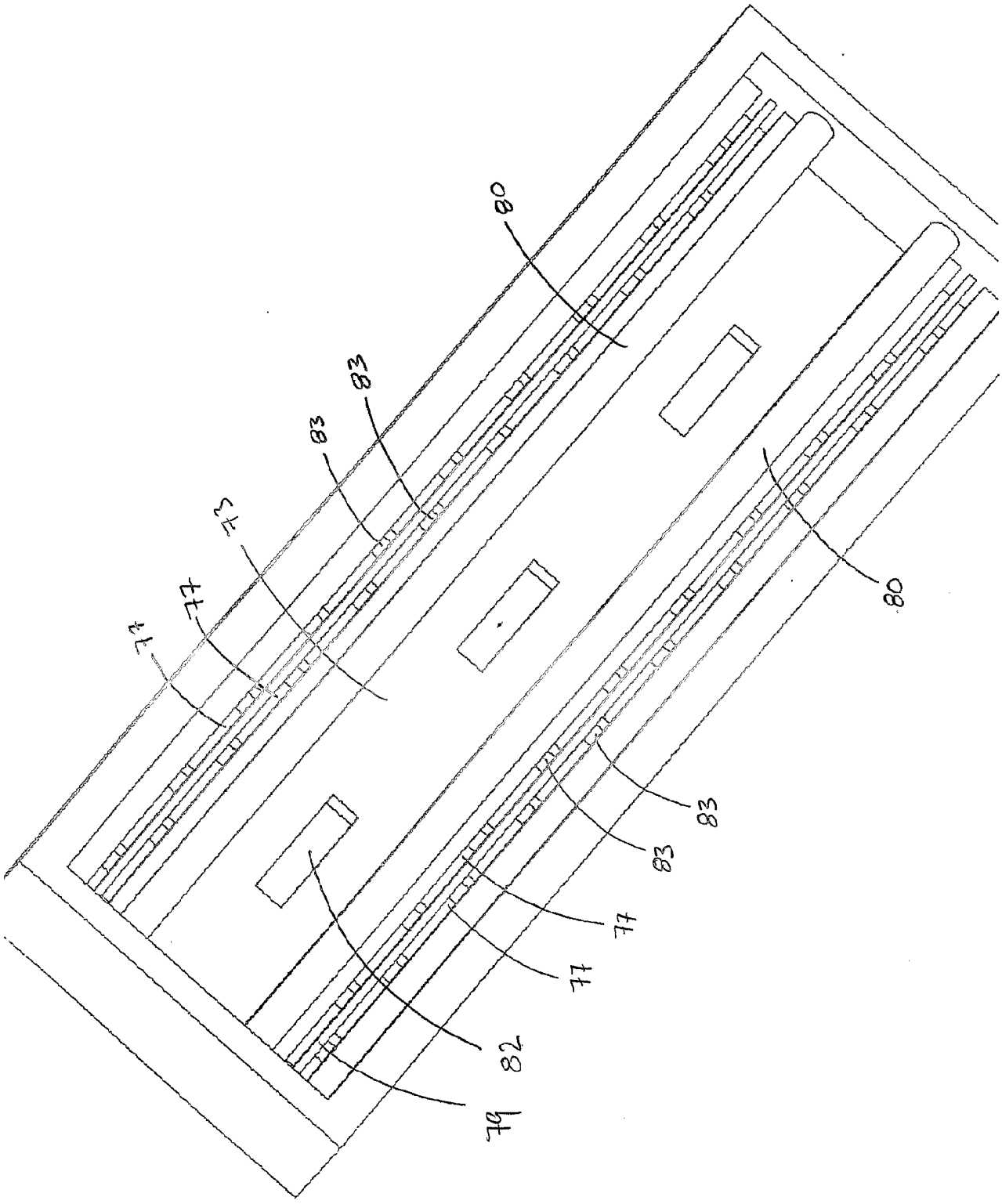
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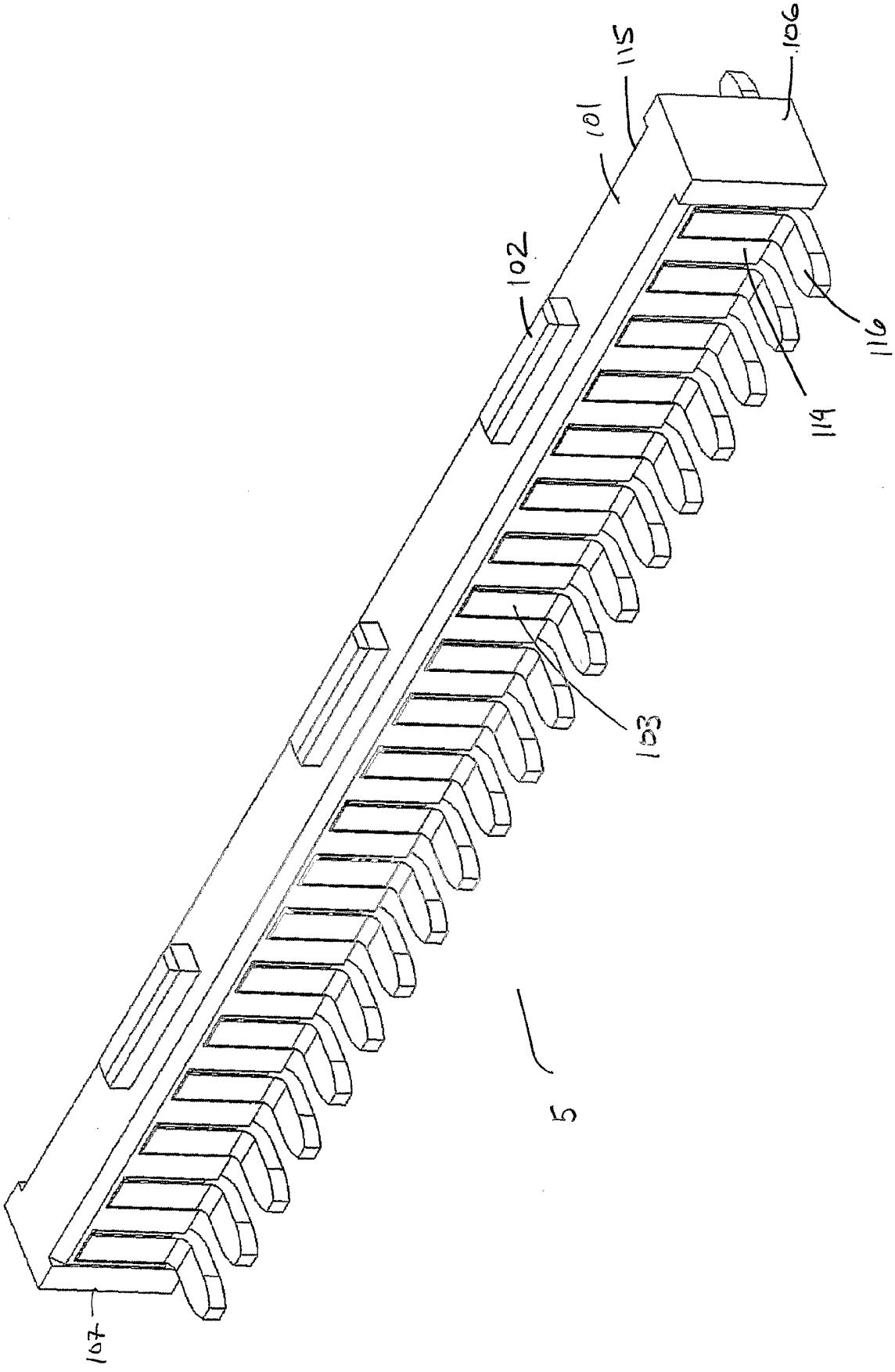
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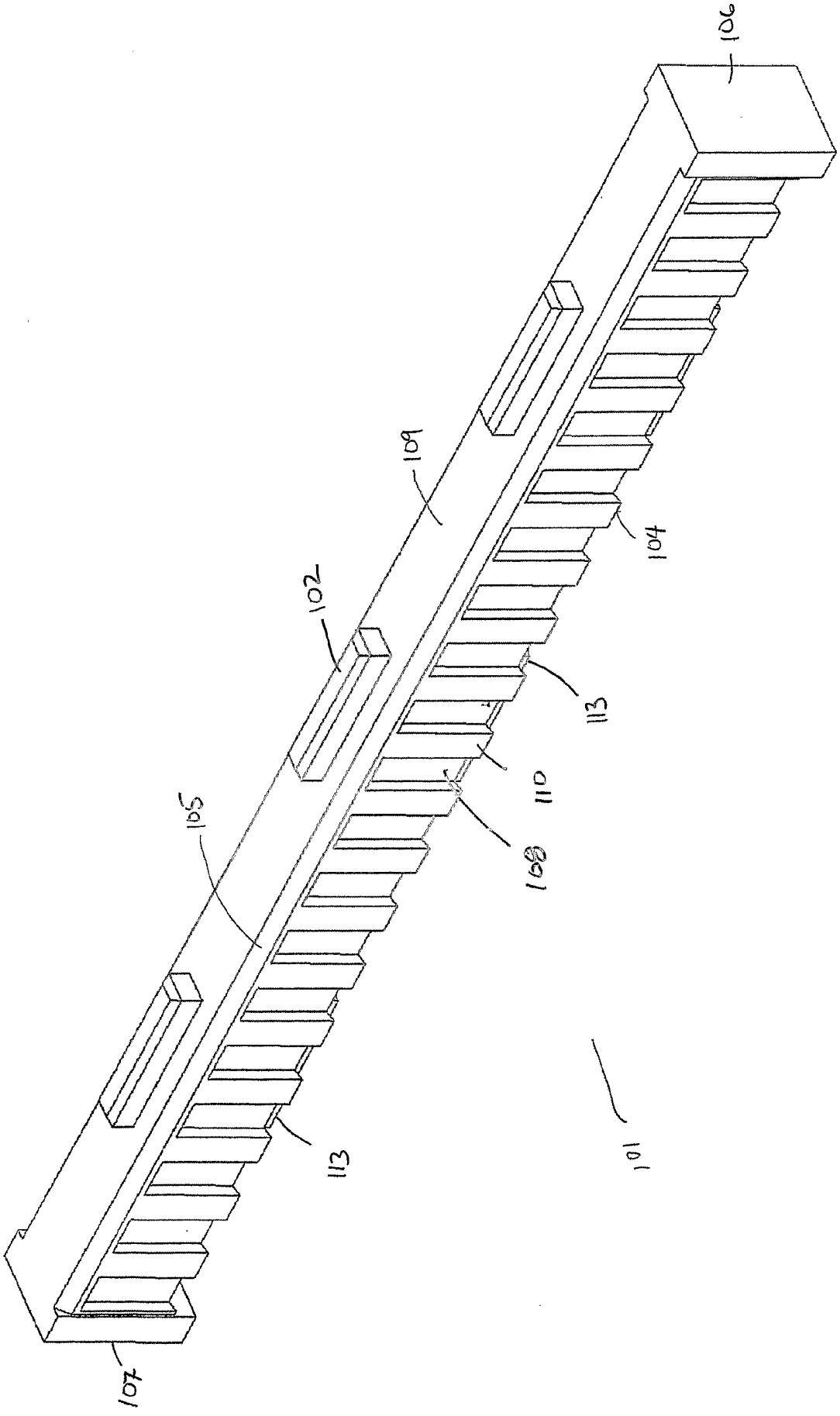
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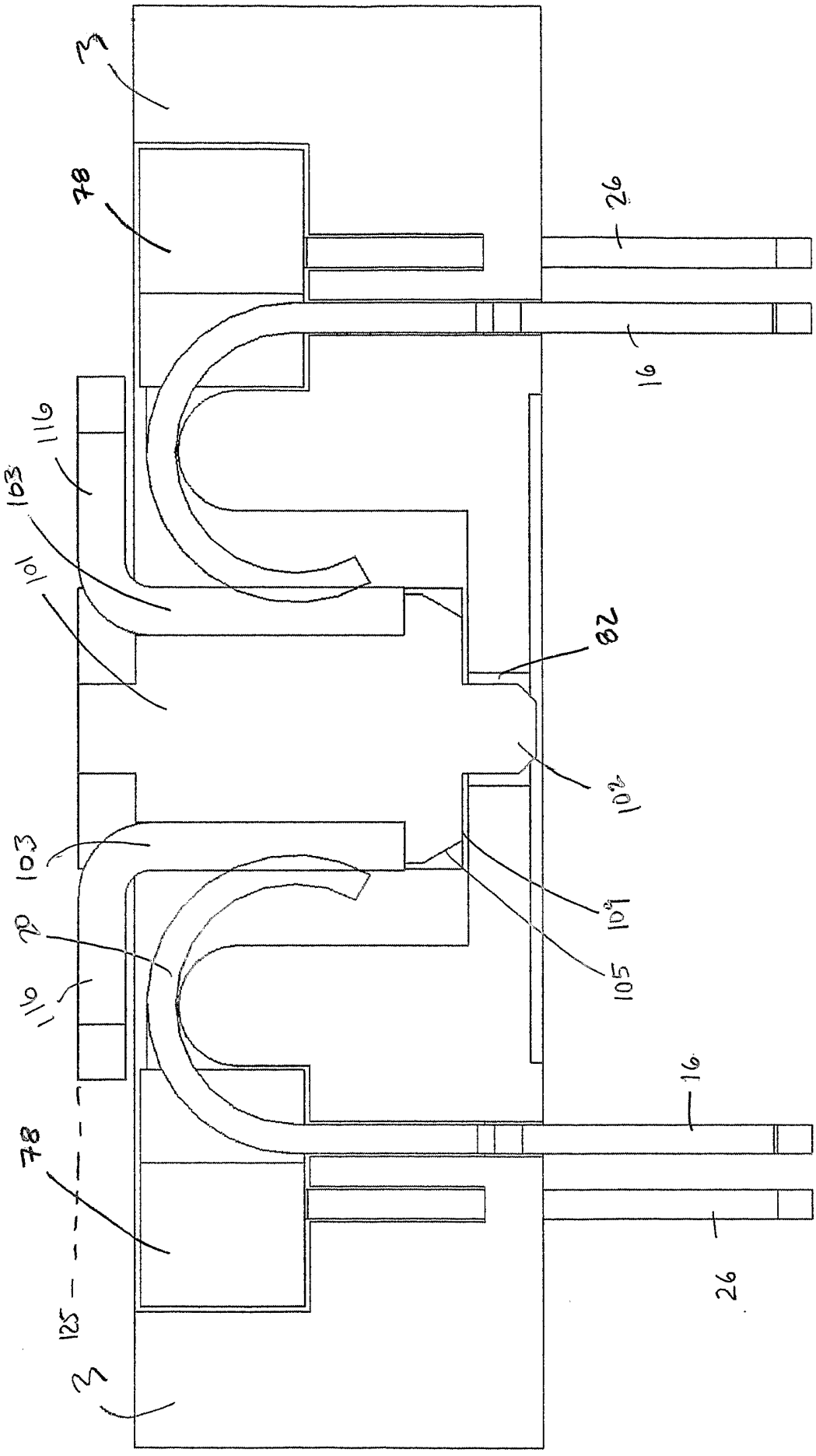
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INTERNATIONAL SEARCH REPORT

Inte nal Application No
PCT/US2004/004136

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01R12/20

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)
IPC 7 H01R

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 practical, 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.
A	WO 93/02491 A (DU PONT) 4 February 1993 (1993-02-04) abstract	1-37
A	US 5 921 787 A (SCHMIDT JUERGEN K ET AL) 13 July 1999 (1999-07-13) abstract	1-37
A	US 2002/028592 A1 (LEE WEI-CHEN) 7 March 2002 (2002-03-07) abstract	1-37

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

☒ Patent family members are listed in annex.

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"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

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Date of the actual completion of the international search	Date of mailing of the international search report
28 May 2004	09/06/2004

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, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Demol, S

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