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(71) Applicant (for all designated States except US):  
**MOLEX INCORPORATED** [US/US]; 2222 Wellington Court, Lisle, Illinois 60532 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **REGNIER, Kent E.** [US/US]; 541 South Grace Street, Lombard, Illinois 60148 (US). **CASHER, Patrick R.** [US/US]; 409 Pinecreek Drive, North Aurora, Illinois 60542 (US). **LONG, Jerry A.** [US/US]; 362 Elm Street, Elgin, IL 60123 (US).

(74) Agents: **SHELDON, Stephen L.** et al.; Molex Incorporated, 2222 Wellington Court, Lisle, Illinois 60532 (US).

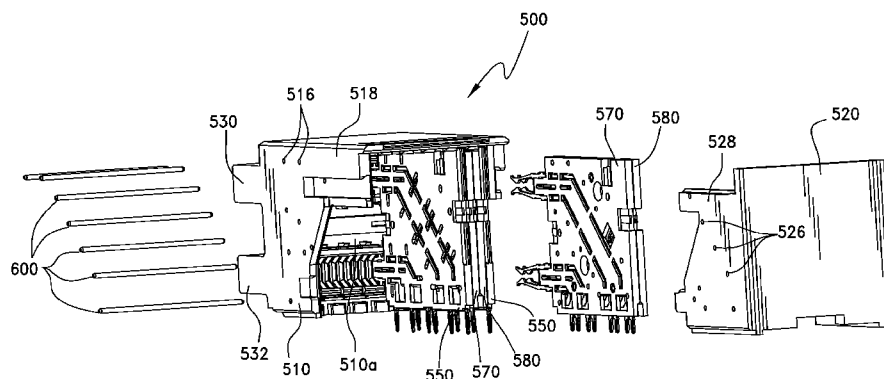
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**FIG.2**

(57) Abstract: A connector assembly is provided that is suitable for modifying the resonant frequency of ground terminals used in conjunction with high data rate signal terminals. Ground terminals may be interconnected with a conductive bridge so as to provide ground terminals with a predetermined maximum effective electrical length. Reducing the effective electrical length of the ground terminal can move the resonance frequencies of the connector outside the operational range of frequencies at which signals will be transmitted.

## **RESONANCE MODIFYING CONNECTOR**

### **BACKGROUND OF THE INVENTION**

**[0001]** This application claims priority to United States Provisional Appln. Serial No. 61/122,216, filed December 12, 2008, which is incorporated herein by reference in its entirety.

### **FIELD OF INVENTION**

**[0002]** The present invention generally relates to connectors suitable for high data rate communications and, more particularly, to a connector with improved resonance characteristics.

**[0003]** While a number of different configurations exist for high data rate connectors, one common configuration is to align a number of terminals in a row so that each terminal is parallel to an adjacent terminal. It is also common for such terminals to be closely spaced together, such as at a 0.8 mm pitch. Thus, high data rate connectors tend to include a number of tightly spaced and similarly aligned terminals.

**[0004]** High data rate communication channels tend to use one of two methods, differential signals or single-ended signals. In general, differential signals have a greater resistance to interference and therefore tend to be more useful at higher frequencies. Therefore, high data rate connectors (e.g., high-frequency capable connectors) such as small form factor pluggable (SFP) style connectors tend to use a differential signal configuration. An increasingly significant issue is that as the frequency of the signals increases (so as to increase the effective data rates), the size of the connector has a greater influence on the performance of the connector. In particular, the electrical length of the terminals in the connector may be such that a resonance condition can occur within the connector if the electrical length of the terminals and the wavelengths of the signals become comparable. Thus, even connector systems configured to use differential signal pairs may experience degradation of performance as operating frequencies increase. Potential resonance conditions in existing connectors tend to make them unsuitable for

use in higher speed applications. Accordingly, improvements in the function, design and construction of a high data rate connector assembly is desirable.

## **SUMMARY OF THE INVENTION**

**[0005]** A connector includes a housing that supports a plurality of ground and signal terminals. The terminals can have contact portions, tail portions and body portions extending between the contact and tail portions. The terminals can be positioned in wafers. The signal terminals can be provided as a pair of signal terminals in adjacent wafers that are used as a differential signal pair. A bridge is extends between two adjacent ground terminals while extending transversely and not in contact with signal terminals positioned between the ground terminals. If desired, multiple bridges may be used. In one embodiment, the bridge can be a pin that is inserted through multiple wafers and may extend transversely past a plurality of pairs of differential signal pairs. In another embodiment, the bridge can be a series of clips that are positioned in the wafers so as to allow each clip to engage a clip in an adjacent wafer. If the bridge is a pin, the pin can be inserted through a first side of the connector, pass through multiple wafers and extends to a second side of the connector. While a single bridge can couple three or more ground terminals, in an embodiment a first bridge can be used to couple a first pair of ground terminals and a second bridge can be used to couple a second pair of ground terminals, even if the first and second pair of ground terminals share a terminal. The ground terminals can include translatable arms that are deflected when the bridge engages the ground terminals.

**[0006]** The connector may include a light pipe structure that is supported by the housing. The connector may include a first opening having ground members and signal terminals adjacent thereto so as to provide a first mating plane. The connector may include a second opening having ground members and signal terminals adjacent thereto so as to provide a second mating plane. The housing may be configured to be mounted on a circuit board with the upper surface of the circuit board forming a plane and the plane of the circuit board lying between the first and second mating plane. Alternatively, the

connector may be configured so that both mating planes are on the same side of the supporting circuit board.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

**[0007]** Various other objects, features and attendant advantages of the present invention will become more fully appreciated as the same becomes better understood when considered in conjunction with the accompanying drawings, in which like reference characters designate the same or similar parts throughout the several views, wherein:

**[0008]** FIG. 1. is a front perspective view of an embodiment of an electrical connector;

**[0009]** FIG. 2 is an exploded perspective of the connector of Fig. 1 with certain components removed for clarity;

**[0010]** FIG. 3 is a front perspective view of the connector of Fig. 1 with the front housing component removed for clarity;

**[0011]** FIG. 4 is a front perspective view similar to that of Fig. 1 but with both of the front and rear housing components removed in order to show the subassembly of internal wafers;

**[0012]** FIG. 5 is a front perspective view similar to Fig. 4 but with the insulation from around one of the ground wafers removed for clarity;

**[0013]** FIG. 6 is a front perspective view similar to that of Fig. 4 but with the endmost ground wafer removed for clarity;

**[0014]** FIG. 7 is a perspective view similar to Fig. 6 but taken from an orientation somewhat beneath the wafer subassembly;

**[0015]** FIG. 8 is a rear perspective view of the connector of Fig. 1 with the rear housing component removed;

**[0016]** FIG. 9 is a perspective view of the wafer subassembly of Fig. 4 but with all of the insulative components removed for clarity;

**[0017]** FIG. 10 is a view of the subassembly of Fig. 9 but with some of the terminals removed for clarity;

**[0018]** FIG. 11 is a front elevational view of the subassembly of Fig. 10;

**[0019]** FIG. 12 is a sectioned perspective view of Fig. 1 taken generally along line 12-12 of Fig. 1;

**[0020]** FIG. 13 is a side elevational view of a pair of ground terminals of Fig. 12;

**[0021]** FIG. 14 is a side elevational view of an alternate embodiment of the ground terminals depicted in Fig. 13;

**[0022]** FIG. 15 is a side-elevational view of still another alternate embodiment of the ground terminals depicted in Fig. 14;

**[0023]** FIG. 16 is a perspective view of four pairs of signal terminals and one ground terminal associated with each row of signal terminals;

**[0024]** FIG. 17 is a side elevational view of the terminals of Fig. 16 showing the relative widths of the body sections of the signal terminals compared to those of the ground terminals;

**[0025]** FIG. 18 is a perspective view similar to Fig. 9 but showing only the ground terminals and the front bridging structure;

**[0026]** FIG. 18A is an enlarged perspective view of a portion of Fig. 18 showing the interaction between the ground terminals and the front bridging structure;

**[0027]** FIG. 19 is a top plan view of the front bridging structure;

**[0028]** FIG. 20 is a rear elevational view of the electrical connector of Fig. 1 with the rear housing component removed and only two ground and two signal wafers inserted into the front housing component;

**[0029]** FIG. 21 is a rear perspective view of the electrical connector of Fig. 1 but with the rear housing component and insulation around the wafers removed for clarity;

**[0030]** FIG. 21A is an enlarged perspective view of a portion of Fig. 21;

**[0031]** FIG. 22 is a rear perspective view similar to Fig. 21 but with bridging pins inserted;

**[0032]** FIG. 22A is an enlarged perspective view of a portion of Fig. 22;

**[0033]** FIG. 23 is a front perspective view of another embodiment of an electrical connector;

**[0034]** FIG. 24 is a side elevational view of the electrical connector of Fig. 23;

**[0035]** FIG. 25 is a perspective view of the electrical connector of Fig. 23 incorporating a light pipe assembly;

**[0036]** FIG. 26 is a front perspective view of the electrical connector of Fig. 23 but with the front and rear housing components removed in order to show the subassembly of internal wafers;

**[0037]** FIG. 27 is a front perspective view similar to Fig. 26 but with the insulation removed from some of the wafers;

**[0038]** FIG. 28 is a side elevational view of Fig. 27;

**[0039]** FIG. 29 is a perspective view of a subassembly of wafers utilizing an alternate form of grounding clips;

**[0040]** FIG. 30 is a sectioned perspective view of Fig. 29 with the insulation above line 30-30 of Fig. 29 removed for clarity;

- [0041] FIG. 30A is an enlarged perspective view of a portion of Fig. 30;
- [0042] FIG. 31 is a perspective view similar to that of Fig. 29 but with the insulation removed from four of the wafers for clarity;
- [0043] FIG. 32 is a perspective view similar to that of Fig. 30A but depicting only two ground and two signal wafers and with the insulation removed from the wafers for clarity;
- [0044] FIG. 33 is a perspective view similar to Fig. 32 but of an alternate embodiment of grounding clips;
- [0045] FIG. 34 is a perspective view similar to Fig. 32 but of another alternate embodiment of ground pins;
- [0046] FIG. 35 is a front perspective view of an alternate embodiment of a ground terminal bridging structure with only a few ground terminals depicted for clarity;
- [0047] FIG. 36 is a rear perspective view of the ground bridging structure and ground terminals of Fig. 35;
- [0048] FIG. 36A is an enlarged perspective view of a portion of Fig. 36; and
- [0049] FIG. 37 is an enlarged perspective view similar to Fig. 36A but depicting an alternate embodiment of contact arms for the bridging structure.

#### **DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS**

[0050] As required, detailed embodiments are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary and the depicted features may be embodied in various forms. Therefore, specific details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the disclosed features in virtually any appropriate manner, including employing various features disclosed herein in combinations that might not be explicitly described.

**[0051]** Small form pluggable (SFP) style connectors are often used in systems where an input/output (I/O) data communication channel is desired. A number of variations in SFP-style connectors exist and different connectors are configured to meet different specifications, such as specifications commonly known as SFP, XFP, QSFP, SFP+ and the like. In general, the SFP-style connectors are configured to mate to modules or assemblies having circuit cards therein and include terminals that, at one end, removably mate with pads on the circuit card and, at an opposite end, extend to traces of a circuit board on which the SFP-style connector is mounted. The details discussed herein, which are based on embodiments of a connector suitable for use with such an SFP-style connector, are not so limited but instead are also broadly applicable to other connector types and configurations as well. For example, without limitation, features of the disclosure may be used for vertical and angled connectors as well as the depicted horizontal connector. In other words, other terminal and housing configurations, unless otherwise noted, may also be used.

**[0052]** In an electrical connector, adjacent terminals, when used to form a high data rate differential pair, electrically couple together to form what can be called a first, or intentional, mode. This mode is used to transmit signals along the terminals that make up the differential pair. However, if other signal terminals are also nearby this differential signal pair, it is possible that one (or both) of the terminals in the differential pair may also electrically couple to one or more of the other terminals (thus forming additional modes). These additional modes are typically undesirable as they can introduce cross-talk that acts as noise relative to the first mode. To prevent such cross-talk, therefore, it is known to shield the differential pair from other signals.

**[0053]** Due to the above-noted tendency to have the terminals located relatively close to each other, pairs of differential signal terminals are often separated from adjacent pairs of differential signal terminals by a ground terminal or a shield. For example, a repeating ground-signal-signal pattern may be used which results in a differential signal pair being surrounded by a ground on each side when the pattern is aligned in a row (e.g., G, S<sup>+</sup>, S<sup>-</sup>, G). A potential issue that arises due to the use of ground terminals as shields is that another mode is created by the coupling between each ground terminal and the pairs of



signal terminals. In addition, the difference in voltage between two different grounds can also cause the grounds to couple together as transient signals pass through the connector. These various couplings create additional modes (and resultant electromagnetic fields) and introduce noise from which the first mode must be distinguished if the communication system is going to operate effectively.

**[0054]** The additional modes generally do not cause problems at low data rates as such additional modes tend to operate at higher frequencies and have less power compared to the first mode and thus do not cause a serious noise issue, assuming the connector is otherwise properly designed. However, as the frequency of the data transmission increases, the wavelength of the signal moves closer to the electrical length of the ground terminals. Therefore, at higher frequencies, it is possible that the transmission frequency will be high enough, and thus the wavelength short enough, to create undesirable resonance in the connector. Such resonance can amplify the secondary modes, which are typically noise, sufficiently to raise the amplitude of the noise as compared to the amplitude of the signal so that it becomes difficult to distinguish between signals and noise. Accordingly, it is desirable for the operating range of a connector to be sufficiently below the resonant frequency of the connector.

**[0055]** As used herein, the term resonant frequency refers to the lowest resonant frequency or fundamental frequency of the connector. Additional resonant frequencies, known as harmonics, exist above the lowest resonant frequency but may generally be ignored since a connector operating within a range below the lowest resonant frequency will also be operating below the harmonics and a connector operating within a range that includes the lowest resonant frequency will likely have issues with respect to noise (absent other steps taken to eliminate or reduce the noise) regardless of whether the operating range also overlaps with any of the harmonics.

**[0056]** The resonant frequency of a connector is a function of the longest effective electrical length between discontinuities or significant changes in impedance along the electrical path which includes the ground terminals. In other words, the resonant frequency depends on the effective electrical length between the points at which two

adjacent ground paths are electrically connected. A non-limiting example of such a connection is a ground plane within a circuit board or card to which both of the adjacent ground terminals are connected. It should be noted that the effective electrical length is a function of numerous factors including the physical length of the terminal, the physical characteristics of the terminal (such as its geometry and surrounding dielectric material, both of which affect its impedance) and the physical length and characteristics beyond the terminal (such as within a circuit board) prior to reaching the discontinuity or intersection.

**[0057]** As an example, the physical distance between discontinuities of a pair of ground terminals having tails mounted in a circuit board and contact ends mated to conductive pads on a circuit card would be equal to the physical length of a ground terminal (defined as the distance from the point at which the terminals reach a common ground or reference plane within the circuit board on which they are mounted to the contact ends of the terminals at which they engage the conductive pads of the circuit card) plus the physical length from the conductive pads on the circuit card to a common ground plane within the circuit card. To determine the effective electrical length, which is measured in picoseconds, between discontinuities, one would also need to factor in characteristics that affect the impedance of the circuit path including the physical geometry of the conductors as well as the dielectric medium surrounding the paths.

**[0058]** A connector that can minimize resonance in the relevant frequency range of signaling can provide certain advantages. It has been determined that decreasing the effective electrical length of the ground terminals, which effectively decreases the length between discontinuities, can provide significant benefits in this regard. In particular, decreasing the electrical length of the terminal so that it is not more than one half the electrical length associated with a particular frequency (e.g., the electrical length between discontinuities is about one half the electrical length associated with a wavelength at the  $3/2$  Nyquist frequency) has been determined to significantly improve connector performance. It should be noted, however, that in certain embodiments the actual electrical length of the terminal is not the effective electrical length of the connector because there is an additional distance traveled outside the connector before a

discontinuity is encountered. For example, the distance from the edge of the contact of the terminal along a contact pad and through a circuit board until reaching a common ground plane is part of the electrical length between discontinuities. Therefore, a connector with ground terminals that have an electrical length of about 40 picoseconds might, in operation, provide an effective electrical length of about 50 picoseconds between discontinuities once the circuit board and contact pad were taken into account. As can be appreciated, this difference can be significant at higher frequencies as a difference of 10 picoseconds in electrical length could result in a connector suitable for about 20 Gbps performance versus one suitable for about 30 Gbps performance.

**[0059]** As it is often not practicable to shorten or reduce the size of the entire connector, the resonance problem in a differential connector that provides rows of terminals has proven difficult to solve in an economical manner. To address this problem, however, it has been determined that one or a plurality of conductive bridges or commoning members can be used to connect multiple ground terminals so as to shorten the distance between discontinuities, thus reducing the electrical length and raising the resonant frequency. This reduced electrical length permits the establishment of a maximum effective electrical length below a desired level and allows higher frequencies to be transmitted over the connector without encountering resonance within the operating range of the connector. For example, placing a conductive bridge or commoning member so that it couples two ground terminals together at their physical mid-point can reduce the effective electrical length of the ground terminals in the connector approximately in half and therefore raises the resonant frequency by approximately doubling it. In practice, since a bridge has a physical length as it extends between the two ground terminals, placing a bridge at or near the physical midpoint may not reduce the electrical length exactly in half but the reduction can be relatively close to half of the original electrical length.

**[0060]** The features described below thus illustrate embodiment where certain features are used to provide a reduced electrical length. If desired, a connector may be provided having a dielectric housing, a first wafer positioned in the dielectric housing and supporting a first conductive ground terminal and a second wafer positioned in the

dielectric housing and supporting a second conductive ground terminal. A pair of signal terminal may be positioned between the first and second ground terminals and at least one conductive bridge may extend between the first ground terminal and the second ground terminal with the conductive bridge electrically connecting the first and second ground terminals and configured so as to provide a reduced maximum effective electrical length of the first and second ground terminals.

**[0061]** If desired, the conductive bridge may be a conductive pin extending through the first and second wafers. Each of the first and second conductive ground terminals may include a contact section at one end for mating with a mating component, a tail at an opposite end for mounting to a circuit member and a generally plate-like body section therebetween. The conductive bridge may be positioned where appropriate and in an embodiment may be positioned so as to electrically connect the first and second ground terminals at a location generally towards a midpoint between the contact ends and the tails of the first and second ground terminals. In one configuration, the reduced maximum effective electrical length of the ground terminals may be less than about 38 picoseconds. In another configuration, the reduced maximum effective electrical length of the ground terminals may be less than about 33 picoseconds. In another configuration, the reduced maximum effective electrical length of the ground terminals may be less than about 26 picoseconds. The conductive bridge may extend transversely past a plurality of pairs of differentially coupled high data rate signal terminals.

**[0062]** If desired, a method of increasing a resonant frequency of an electrical connector above a desired operational frequency range of the connector may be utilized. Such method includes determining the desired operational frequency range of the connector, and providing first and second spaced apart ground members with the first ground member defining at least part of a first electrical path and the second ground member defining at least part of a second electrical path. A differential signal pair can be provided between the first and second ground members and the approximate maximum effective electrical length between discontinuities along the first and second electrical paths is determined. An initial resonant frequency is determined based on the approximate longest effective length between the discontinuities along the first and

second electrical paths and a maximum desired effective electrical length between the discontinuities is determined in order to increase the resonant frequency of the electrical connector above the desired operational frequency range. At least one conductive bridge is connected between the first and second ground terminals to reduce the effective electrical length between discontinuities along the first and second ground members to a length that is less than the maximum desired effective electrical length.

**[0063]** If desired, determining the maximum effective electrical length between discontinuities along the first and second electrical paths may include simulating an electrical system. The simulating step may include analyzing physical characteristics of the ground members including their length, geometry and the dielectric medium surrounding the ground members. The simulating step may include analyzing additional circuit components that define at least part of the first and second electrical paths. Determining the maximum effective electrical length between discontinuities along the first and second electrical paths may include testing the electrical connector.

**[0064]** Referring now to the Figures, Figs. 1-13 illustrate an embodiment of a connector 500 that includes a first housing component 510 and a second housing component 520. The first housing component 510 includes a first projection 530 and a second projection 532, both of which have a card slot 534 configured to receive circuit cards (not shown) that are supported by a corresponding mating module (not shown). As depicted, each card slot 534 includes terminal receiving grooves 536 extending along the top and bottom inner surfaces thereof.

**[0065]** Pin receiving apertures 512 may be provided in a first side 514 of first housing component 510 and pin receiving apertures 516 aligned with pin receiving apertures 512 may be provided in a second side 518 of first housing component 510. Similarly, pin receiving apertures 522 may be provided in a first side 524 of second housing component 520 and pin receiving apertures 526 aligned with pin receiving apertures 522 may be provided in a second side 528 of second housing component 520. Depending upon the assembly process used, apertures may not be necessary on both sides of first housing

component 510 nor on both sides of housing component 520. In certain instances, apertures in the first and second housing components may not be necessary at all.

**[0066]** As depicted, the front housing component 510 includes a cavity 540 into which a plurality of insert-molded terminal wafers 550, 570, 580 may be inserted. As depicted, each wafer includes two pairs of conductive terminals with a plastic insulative body insert-molded around the terminals. Each terminal has a contact end for mating with a pad (not shown) on a mating circuit card, at least one tail for engaging a plated hole in a circuit board on which connector 500 is mounted, and a body connecting the contact end and the at least one tail.

**[0067]** More particularly, referring to Figs. 5, 9, 10, 12, ground wafer 550 includes four ground terminals 552, 554, 556, 558, each having a mating end 552a, 554a, 556a, 558a depicted as a deflectable contact beam or spring arm at one end for engaging a mating component (not shown) and tails 552b, 552b', 554b, 556b, 556b', 558b depicted as compliant pins for engaging a circuit member (not shown) on which connector 500 is mounted. Relatively large or wide body sections 552c, 554c, 556c, 558c extend between mating ends 552a, 554a, 556a, 558a and tails 552b, 554b, 556b, 558b, respectively, of each terminal. In addition, each ground terminal 552, 554, 556, 558 includes a plurality of deflectable tabs or fingers 560 extending therefrom and a single, relatively wide tab 562 generally adjacent mating end 552a, 554a, 556a, 558a. If desired, fingers 560 may be slightly angled towards one of the sides of housing components 510, 520. A first joining member 564 may be provided between the longer two ground terminals 552, 554, and second joining member 566 may be provided between the shorter two ground terminals 556, 558.

**[0068]** Signal wafers 570, 580 can be configured in a substantially similar manner with respect to each other and can be somewhat similar to ground wafers 550. As depicted in Figs. 16, 17, each first signal wafer 570 has four signal terminals 572, 574, 576, 578 with a mating end 572a, 574a, 576a, 578a depicted as a deflectable contact beam or spring arm at one end for engaging a mating component (not shown) and a tail 572b, 574b, 576b, 578b depicted as a compliant pin for engaging a circuit member (not

shown) on which connector 500 is mounted. Relatively small or narrow body sections 572c, 574c, 576c, 578c extend between mating ends 572a, 574a, 576a, 578a and tails 572b, 574b, 576b, 578b, respectively, of each terminal. The difference in width between body sections 572c, 574c, 576c, 578c of ground terminals 552, 554, 556, 558 and body sections 572c, 574c, 576c, 578c of signal terminals 572, 574, 576, 578 is best seen in Fig. 17. Signal terminals 572, 574, 576, 578 further include transition sections 572d, 574d, 576d, 578d between body sections 572c, 574c, 576c, 578c and tails 572b, 574b, 576b, 578b in order to offset the tails from the body sections.

**[0069]** Second signal wafer 580 includes four signal terminals 582, 584, 586, 588 that, except as noted below, are substantially identical to the signal terminals 572, 574, 576, 578 of the first signal wafer 570 and the description of which is not repeated herein. However, as can be appreciated from Fig. 11, the tails 572b, 574b, 576b, 578b of first wafer 570 and the tails 582b, 584b, 586b, 588b of second wafer 580 are offset from the plane of their respective body sections in opposite directions towards the other wafer so that the tails of the signal terminals of both wafers are aligned in a single row. Upon insertion of the wafers 550, 570, 580 into the housing cavity 510a, the contact sections of the terminals are positioned in and may be supported by the terminal receiving grooves 536 so as to form a row of contact ends. In operation, the row of contact sections facilitates mating between the connector and pads on circuit cards which may be inserted into card slots 534.

**[0070]** As depicted, the wafers are positioned within cavity 510a in a repeating pattern with two signal wafers 570, 580 positioned next to each other to create pairs of horizontally aligned differential-coupled signal terminals. The depicted terminals are broadside-coupled, which has the benefit of provide a stronger coupling between the terminals that form the differential pair, but unless otherwise noted, broadside coupling is not required. Ground wafers 550 are positioned on both sides of each pair of signal wafers in order to achieve the desired electrical characteristics of the signal terminals and to create a repeating ground, signal, signal, pattern (e.g., G, S<sup>+</sup>, S<sup>-</sup>, G, S<sup>+</sup>, S<sup>-</sup>, G). If desired, other patterns of wafers could be utilized such as adding additional ground wafers (e.g., G, S<sup>+</sup>, S<sup>-</sup>, G, G, S<sup>+</sup>, S<sup>-</sup>, G) to further isolate the signal terminals and/or

additional signal wafers could be added in which the additional signal terminals would typically be used for “lower” speed signals (e.g., G, S<sup>+</sup>, S<sup>-</sup>, G, S, S, S, G, S<sup>+</sup>, S<sup>-</sup>, G). In addition, if desired, rather than molding two separate signal wafers 570, 580 and then position them adjacent to each other during the assembly process, it is also possible that the two signal wafers could be combined so as to provide a single wafer molded around all of the terminals. In addition, if desired, the wafers need not be insert molded. For example, the wafer housing could be molded in a first operation and the terminals inserted into the wafer housing in a second, subsequent operation. Insert molded wafers, however, are beneficial to precisely control the orientation of terminals supported by the wafer.

**[0071]** In order to achieve the desired electrical characteristics, the depicted embodiment illustrates a connector with pins 600 (e.g., the pins providing the electrically conductive bridges) to be inserted once wafers 550, 570, 580 are loaded into the first and second housing components 510, 520. The pins 600 engage and deflect fingers 560 of the ground terminals to couple together multiple ground terminals and thus form electrically conductive bridges. More particularly, as best seen in Fig. 9, a first pin 600a engages a first set of aligned fingers 560' of ground terminals 552, a second pin 600b engages a second set of aligned fingers 560" of ground terminals 552, and this can be repeated with additional pins so that ground terminals 552 are interconnected or commoned at multiple locations. It should be noted that the fingers 560 may be somewhat deflected out of the plane of the body section of each ground terminal but, for clarity, such deflection is not shown in the drawings.

**[0072]** The bridges (depicted as pins 600 in Figs. 1-28) couple fingers 560 that extend from the body portions 552c, 554c, 556c, 558c of the ground terminals 552, 554, 556, 558. It has been determined that for a multi-row connector design, the height of the connector and the length of the ground terminals make the inclusion of a number of bridges desirable so as to ensure the effective electrical length is short enough. The pins 600 may be formed of a sufficiently conductive material such as a copper alloy with a desirable diameter, such as between 0.4 mm and 0.9 mm. It has been determined that such a construction allows for a pin 600 that has sufficient strength to allow for insertion



while avoiding any significant increase in size of the connector. As can be appreciated, a shorter connector may be able to provide ground terminals with a desirable electrical length while only using one bridge. It is expected, however, that a plurality of bridges will be beneficial in many connector configurations.

**[0073]** For connector with multiple rows of contacts, such as those depicted, the terminals have different lengths, depending on the row in which they are positioned. Consequentially, a different number of bridges can be used with each row of ground terminals to ensure the corresponding row of ground terminals has the desired maximum electrical length. For example, in Fig. 4, the top row of ground terminals 552 in the first projection 530 is coupled to seven pins 600 while the opposing row of ground terminals 554 is coupled to five pins 600. The top row of ground terminals 556 in the second projection 532 is coupled to three pins 600 while the opposing row of ground terminals 558 is coupled to one pin 600. Thus, in the depicted embodiment, the number of pins in subsequent lower rows decreases by two as compared to the prior upper row. This helps ensure a desirable performance while minimizing complexity and cost.

**[0074]** The bridges extend transversely across the signal terminals, such as terminals 572, 582 that form the differential pair 540 (Fig. 11). To minimize electrical interference and changes in impedance, each bridge may be positioned a distance 588 from the upper surface of the signal terminals 572, 582. In an embodiment, the distance between the bridge and the terminals 572, 582 that form differential pair 540 is sufficient so that there is greater electrical separation between the bridge and the differential pair 540 than there is between the two terminals that form the differential pair.

**[0075]** As described above, the pairs of upper and lower ground terminals 552, 554 in the first projection 530 may be coupled by a first joining member 564 proximate to ground tails 552b, 554b and the pairs of upper and lower ground terminals 556, 558 in the second projection 532 may be coupled by second joining member 566 proximate to ground tails 556b, 558b. These joining members can help further reduce potential differences between ground terminals and improve the overall performance of connector 500. As can be appreciated from Figs. 13-15, alternative embodiments of the ground

terminals may be provided such as enclosing the space between the body sections 552c, 554c of ground terminals 552, 554 to create a single ground terminal body 552c' to shield both of the signal terminals 572, 574 in the upper and lower rows of first projection 530. Such a terminal could include fingers 560 extending from the upper and lower edges of the body or might include fingers 560" extending from only one side (such as depicted in Fig. 14) or could include pins 600 extending through the middle of the ground terminals with an interference fit (as depicted in Fig. 15).

**[0076]** Referring to Fig. 19, an embodiment of a bridge is illustrated. The bridge is provided by a clip 630 which is inserted into the first housing component 510 prior to insertion of wafers 550, 570, 580. The clip 630 is conductive and may be one piece as shown. The clip 630 can include a plurality of spaced apart engagement notches 631 that engage projections on first housing component 510 so that the first housing component 510 retains the clip 630 therein with a press-fit type engagement. The clip 630 includes a plurality of spaced apart receiving channels 632, which can be on an edge opposite notches 631, with each channel having a pair of opposing spring arms 633 therein. As depicted, the distance between spring arms 633 is less than the thickness of wide tab 562 in order to establish a good electrical connection between the spring arms 633 and wide tab 562 upon insertion of wide tab 562 between spring arms 633. If desired, a bump or projection 634 may be provided on each spring arm 633 in order to increase the reliability of the contact between the spring arms and the wide tab.

**[0077]** Clip 630 is preferably formed of an appropriate conductive material having sufficient spring and strength qualities so as to reliably retain clip 630 within front housing component 510 and maintain a reliable connection between spring arms 633 and wide tabs 562. It may be desirable to use clip 630 in situations in which it is difficult to insert a pin 600 near the mating ends 552a, 554a, 556a, 558a of ground terminals 552, 554, 556, 558. Depending on the available space within the connector 500, channels 632 may be omitted from the outer lateral edges of clip 630 and replaced by a single spring arm 633 in which case the wide tabs of the outer ground wafers will only be engaged by a single spring arm 633. Although clip 630 is depicted in Figs. 1-28 as a one-piece

member, if desired, clip 630 could be formed of multiple components 890 (Figs. 29-34) that are secured within front housing component 510.

**[0078]** During the assembly process, the wafers supporting the terminals may be inserted into the housing in a number of different manners. Some examples of the assembly process include: 1) individually loading or stitching the wafers into the housing in the sequence in which they are aligned in the housing (e.g.,  $G S^+ S^- G S^+ S^- G$ ); 2) inserting all of the wafers of a first type (e.g., all of the ground wafers 550) into cavity 540, inserting all of the wafers of a second type (e.g., all of the first signal wafers 570) into cavity 540 and this process repeated until the cavity is fully populated; 3) configuring the wafers carrying the signal terminals so that the two signal wafers 570, 580 are coupled together first and then inserting the coupled wafer pair into the housing; or 4) coupling or positioning all of the wafers together in the desired pattern and then inserting the coupled subassembly of wafers into cavity 540 in a single loading operation.

**[0079]** For the first three assembly processes listed above, after the wafers 550, 570, 580 have been inserted into first housing 510, pins 600 can be inserted into connector 500. If the fingers 560 are all co-planar with body sections 552c, 554c, 556c, 558c, pins 600 may be inserted from either side of the connector. More specifically, pins 600 could be inserted through the pin receiving apertures in either side of first housing component 510 and through the pin receiving apertures in either side of second housing component 520. If desired, the pins 600 may extend essentially the entire width of connector 500 and through the pin receiving apertures on both sides of first housing component 510 and second housing component 520.

**[0080]** As described above, fingers 560 may be slightly angled toward one of the sides of the respective first and second housing components 510, 520 and away from the direction of insertion of the pins 600 in order to ease insertion of the pins. As can be appreciated, in such case, it is preferable that the fingers 560 are all angled in the same direction (e.g., toward the same side) and the pins 600 could be inserted from the side opposite the side towards which the fingers are angled. In other words, fingers 560 may be bent out of the plane of the body section of their respective ground terminal and pins

600 can be inserted in the same direction as the fingers extend out of the plane of the body section.

**[0081]** If wafers 550, 570, 580 are coupled or positioned together in the desired pattern and then inserted as a subassembly of wafers into cavity 540 in a single loading operation as described above as the fourth assembly process, pins 600 could be inserted as described above once the wafer subassembly has been inserted into cavity 510a and second housing component 520 secured to first housing component 510. In the alternative, shorter pins that only extend between the opposite sides of the wafer subassembly and not through the sidewalls of first or second housing components 510, 520 could be inserted into the wafer subassembly prior to insertion of the subassembly into first housing wafer 510. In other words, the wafer subassembly may be joined by the pins and the entire subassembly inserted as a group into cavity 510a. In such case, apertures in the first and second housing components 510, 520 would not be necessary.

**[0082]** Regardless of which assembly process is used, if first housing component 510 includes a clip 630, during insertion of ground wafers 550, the wide tab 562 of each ground terminal 552, 554, 556, 558 will slide into a receiving channel 632 and between spring arms 633 in order to establish a good electrical connection between clip 630 and one of the ground terminals 552, 554, 556, 558. In other words, in an embodiment the clip can be first inserted into the housing component 510 and then the wafers can be inserted in the housing component 510 so that the ground terminals engage the clip 630.

**[0083]** Referring to Figs. 23-28, an embodiment of a connector 700 is depicted that is similar to that of Figs. 1-22A except that the seating plane 702 (i.e., the plane of the circuit board on which the connector is mounted) has been moved upward so that the plane of one of the circuit card slots (lower slot 732 as depicted) is positioned below the plane of upper surface 52 of the circuit board 50. Connector 700 includes a housing 710 with a first surface 712, a first side 716 and second side 718. Apertures 714 in the first side allow pins 740 to be inserted into the connector 700. Projection 726, which includes first surface 727 and second surface 728, includes two vertically spaced apart card slots

730, 732 therebetween. The card slots 730, 732 may be chamfered and include terminal receiving grooves 734 for supporting terminals 750 inserted therein.

**[0084]** The sides of the connector 700 may include a curved wall 713 configured to retain a light pipe and may further include a shoulder 720 to help support the light pipe. If desired, a front face 729 of projection 726 may include apertures, such as aperture 736, to support a light pipe assembly 738. Slots 740 may be used to support shielding members (not shown).

**[0085]** The depicted housing 710 includes a block 722 that extends past an edge 54 of the circuit board 50 while the upper surface 52 of the circuit board 50 supports the connector. As can be appreciated, the depicted connector, while providing a press-fit (or thru-hole) mounting interface with respect to the circuit board, also allows the lower circuit card slot 732 to be positioned below the upper surface 52 of the circuit board. Thus, the depicted embodiment provides an advantageously compact and low profile package.

**[0086]** As with connector 500, connector 700 includes an alternating array of wafers 745, 746, 747. Wafers 745, 746, 747 are similar in construction to wafers 550, 570, 580 except that the seating plane 702 of connector 700 has been moved as compared to the seating plane of connector 500. In addition, ground wafer 745 is different from ground wafer 550 in that it includes both ground terminals and signal terminals therein. More specifically, as best seen in Figs. 27, 28, ground wafer 745 includes four terminals with the topmost and bottommost terminals 751, 752 being configured as ground terminals with wide body sections 751c, 752c and resilient tabs or fingers 756 extending therefrom. The middle two terminals 762, 764 are configured in a manner similar to the signal terminals 755 with the body sections 762c, 764c thereof being substantially narrower than the body sections 751c, 752c of the ground terminals.

**[0087]** As depicted, a first row 770 of terminals includes a plurality of pairs of differentially coupled high data rate signal terminals 771 with ground terminals 751 on opposite sides of each pair. Pins 780 engage fingers 756 of ground terminals 751 to common the ground terminals as described above in order to provide a desired maximum

effective electrical length. A second row 772 of terminals 762 within the first card slot 730 has a similar configuration but does not include high data rate terminals and commoned ground terminals and thus the upper card slot 730 (which includes the first and second rows 770, 772) is configured for a high data rate version of the SFP-type connector (as SFP-style connectors include two high data rate channels in one of the two rows). The second card slot 732 is configured in a manner that is similar to the first card slot 730 as it has a third row 774 of terminals 764 not including commoned ground terminals while a fourth row 776 of terminals includes a pair of differentially coupled high data rate signal terminals 778 with commoned ground terminals 752 on opposite sides of each pair. Thus, both the first and second card slots 730, 732 are suitable for use in a high data rate variant of a SFP connector but the second card slot is rotated 180 degrees with respect to the orientation of the high data rate terminals surrounded by commoned ground terminals. Terminals 762, 764 of the middle two rows of terminals can be used as desired for lower-speed signals and/or power or the like. In an embodiment, the high data-rate terminals rows may be configured so that they are suitable for 17 Gbps performance or even 20 or 25 Gbps. As can be appreciated, flipping the orientation of the second card slot with respect to the first card slot is advantageous from a standpoint of signal separation in a dense package but is not required.

**[0088]** Figs. 29-32 illustrate a subassembly of wafers similar to that of Figs. 1-22A but which include an alternate embodiment of a structure for bridging the ground terminals in the wafers. Accordingly, like reference numbers are used with respect to like elements and the description of such elements is omitted. Wafers 850, 870, 880 include apertures 810 therethrough in which individual conductive, identically shaped, resilient ground clips 812, 814 are positioned. Ground clips 812, 814 may be inserted into apertures 810 either before or after molding of the plastic insulation around wafers 850, 870, 880. The ground clips 812, 814 are configured to extend slightly beyond at least one side surface of its respective wafer so that each clip engages the clips on opposite sides thereof. In addition, the ground clips 812 associated with each ground wafer 850 also engage a tab 816 extending away from body section 552c, 554c, 556c, 558c of the ground terminals 552, 554, 556, 558. Wafers 870, 880, which include the high data rate signal terminals, are positioned between two ground wafers 850 so that grounding clips 814 of

the signal wafers engage the grounding clips 812 of the ground wafers and form a continuous electrical bridge that extends between ground terminals and transversely to and spaced from an edge of the high data rate signal terminals.

**[0089]** As best seen in Fig. 32 due to the removal of the plastic insulation of wafers 850, 870, 880, the individual ground clips 812 secured within each ground wafer 850 conductively engage a tab 816 associated with each ground terminal 552, 554, 556, 558. However, the individual ground clips 814 secured within each signal wafer 870, 880 are spaced from the edge of the closest signal terminal by a sufficient distance (similar to distance 588 of Fig. 11) so as to avoid electrical interference and impedance affects on the signal terminals. The grounding clips may be formed of sheet metal or another resilient conductive material and, as depicted, are generally U-shaped or oval-shaped.

**[0090]** When the wafers 850, 870, 880 are assembled, the ground clips 812, 814 combine to serve the same purpose as pins 600, namely, to interconnect the adjacent ground terminals along the length thereof in order to reduce the electrical length between discontinuities along the ground terminals. Thus, as with the embodiment of Figs. 29-32, grounding clips 812, 814 permit the ground terminals 552, 554, 556, 558 to have a maximum effective electrical length that is substantially shorter than the effective electrical length of the terminals.

**[0091]** Referring to Fig. 33, another embodiment of individual ground clips is disclosed. As with ground clips 812, 814 discussed above, ground clips 820, 822 are identically shaped, resilient conductive members and may be formed of conductive sheet metal. Ground clips 820, 822 are similar in shape to ground clips 812, 814 except that they include an internal resilient, relatively small U-shaped section so that clips 820 may resiliently and conductively engage tabs 824 of the ground terminals.

**[0092]** In another embodiment, the resilient ground clips 812, 814 may be replaced by cylindrical posts 830 (Fig. 34) that are retained within each wafer 850, 870, 880. Upon assembling the wafers side-by-side, the posts 830 will combine to resemble pins 600. In other words, if desired, pins 600 may be formed of multiple components rather than utilizing a one-piece construction.

**[0093]** Figs. 35-36A illustrate a subassembly of ground terminals that utilize an alternate embodiment of a structure for electrically bridging such terminals. The ground terminals are similar to those shown in Fig. 10 and like reference numbers are used with respect to like elements and the description of such elements is omitted. Comparing Fig. 35 to Fig. 10, it can be seen that all of signal terminals and all but a few of the ground terminals have been removed for clarity. More specifically, all of the terminals of Fig. 10 have been removed except for those on the outer ends of the terminal array. A plate-like bridging structure is associated with each row of ground terminals. An upper row of ground terminals 552 has a first plate-like bridging structure 952 associated therewith, a second row of ground terminals 554 has a second plate-like bridging structure 954 associated therewith, a third row of ground terminals 556 has a third plate-like bridging structure 956 associated therewith and a lower row of ground terminals 558 has a fourth plate-like bridging structure 958 associated therewith. Each of the three upper bridging structures 952, 954, 956 are shaped as bent plates formed with multiple, interconnected, generally planar segments while the fourth bridging structure 958 is generally planar.

**[0094]** Each bridging structure includes a plurality of pairs of spaced apart, opposed resilient spring arms 970 positioned in a three-dimensional array and aligned with fingers 560 of each ground terminal. Each arm 970 is formed by stamping and forming the sheet metal so as to create the downwardly depending resilient arms and creating a window 972 in the sheet metal. While not shown, each signal contact is generally aligned with one of the edges 974 of window 972 opposite the edge 976 from which the spring arm depends. Each arm 970 is shaped so as to taper inward towards its opposing arm in order to create an enlarged inlet 978 to facilitate insertion of finger 560 into engagement with each pair of arms. Upon insertion of finger 560, spring arms 970 deflect outward in a direction generally perpendicular to the plane of the body sections of the ground terminals.

**[0095]** Fig. 37 depicts an alternate embodiment of a plate-like bridging structure 980 in which each pair of spring arms 970 is replaced by a single spring arm 982 that is deflectable in a direction generally perpendicular to the plane of the segment of the bridging structure from which it depends. In other words, the single spring arms 982 are



configured and positioned so as to be aligned with fingers 560 and deflect in the direction that each finger 560 extends away from its ground terminal.

**[0096]** As depicted, the bridging structures 952, 954, 956, 958, 980 are formed of sheet metal so as to have the desired electrical and mechanical characteristics. It should be noted that with respect to the embodiment depicted in Figs. 35-37, fingers 560 were formed so as to be resilient and deflect to some extent upon engagement by pins 600. Since the spring arms 970, 982 of the plate-like bridging structures are resilient, it is not necessary for fingers 560 be resilient when used with the plate like bridging structures depicted herein.

**[0097]** It should be noted that, in general, the longest section of the ground path between discontinuities will tend to control the resultant resonant frequency. Therefore, an electrical path that has a number of closely spaced bridges to create a series of short electrical lengths between discontinuities while also having a longer section between discontinuities will have an effective electrical length determined by the longer section between discontinuities. Consequently, it is beneficial to ensure that the maximum or longest effective electrical length between discontinuities is below or less than a predetermined length.

**[0098]** When designing a high data rate connector, a desired operational frequency range of the connector is typically known. Once the designer has designed a connector (or obtained a pre-existing connector), the connector can be analyzed to determine a maximum effective electrical length between discontinuities along adjacent ground paths in which the connector will be used. While this length is primarily the electrical length of the ground terminals, other factors contribute to the effective electrical length including any distance along the circuit path outside of the connector prior to reaching a discontinuity as well as other factors that affect the characteristics of the conductors.

**[0099]** Based upon the maximum effective electrical length between discontinuities, an initial or unmodified resonant frequency can be determined. If the initial or unmodified resonant frequency is too low (which means that the operational range of the connector will overlap with the resonant frequency), a maximum desired effective

electrical length is determined such that the resonant frequency for such effective length will be sufficiently above the desired operational frequency range of the connector. At that point, one or more conductive bridges, such as those incorporating the structures disclosed herein, may be used to interconnect adjacent ground members and reduce the effective electrical length between discontinuities to a length less than the maximum desired effective length and thus increase the resonant frequency of the ground structure of the connector. In the alternative, the maximum desired effective length could be determined (based upon a desired resonant frequency) prior to determining the maximum effective electrical length between discontinuities. It should be noted that analyzing the connector to determine the longest effective electrical length between discontinuities and the desired maximum electrical length can be performed either by simulation of the circuitry or by actual measurement if physical samples of the connector exist.

**[00100]** It has been determined that a stacked SFP type connector with ground terminals that have an effective electrical length of about less than 38 picoseconds is suitable for use with signaling frequencies of about 8.5 GHz, which should provide about a 17 Gbps connector per differential signal pair when using a non-return to zero (NRZ) signaling method.

**[00101]** Careful placement of the bridges may allow the effective electrical length of the ground terminals to be reduced to about 33 picoseconds, which may be suitable for signaling frequencies of about 10 GHz (and thus may be suitable for about 20 Gbps performance). If the bridges are configured to be even closer together physically, the effective electrical length can be reduced to about 26 picoseconds, which may be suitable for transmitting signals at about 13 GHz or 25 Gbps performance (assuming NRZ signaling methodology). As can be appreciated, therefore, spacing the bridges closer together (and thus increasing the number of bridges) will have the tendency to reduce the effective electrical length of the ground terminals and consequentially help make the connector more suitable for higher frequencies and higher data rates. The desired maximum effective electrical length will vary depending on the application and the frequencies being transmitted.

**[00102]** In an embodiment, the connector can be configured so as to reduce the effective electrical length of a plurality of ground terminals so as to shift the resonant frequency sufficiently, thereby providing a substantially resonance free connector up to the Nyquist frequency, which is one half the sampling frequency of a discrete signal processing system. For example, in a 10 Gbps system using NRZ signaling, the Nyquist frequency is about 5 GHz. In another embodiment, the maximum electrical length of a plurality of ground connectors may be configured based on three halves ( $3/2$ ) the Nyquist frequency which, for a 10 Gbps system is about 7.5 GHz, for a 17 Gbps system is about 13 GHz and for a 25 Gbps system is about 19 GHz. If the maximum electrical length is such that the resonance frequency is shifted out of the  $3/2$  Nyquist frequency range, a substantial portion of the power transmitted, potentially more than 90 percent, will be below the resonant frequency and thus most of the transmitted power will not cause a resonance condition that might otherwise increase noise within the system.

**[00103]** It should be noted that the actual frequency rate and effective electrical lengths vary depending upon the materials used in the connector, as well as the type of signaling method used. The examples given above are for the NRZ method, which is a commonly used high data rate signaling method. As can be appreciated, however, in other embodiments two or more ground terminals may be coupled together with a bridge at a predetermined maximum electrical length so that the connector is effective in shifting the resonance frequency for some other desired signaling method. In addition, as is known, electrical length is based on the inductance and capacitance of the transmission line in addition to the physical length and will vary depending on geometry of the terminals and materials used to form the connector. Thus, similar connectors with the same basic exterior dimensions may not have the same effective electrical length due to construction differences.

**[00104]** It will be understood that there are numerous modifications of the illustrated embodiments described above which will be readily apparent to one skilled in the art, such as many variations and modifications of the resonance modifying connector assembly and/or its components, including combinations of features disclosed herein that are individually disclosed or claimed herein, explicitly including additional combinations

of such features, or alternatively other types of signal and ground contacts. For example, bridging structures can be used with arrays of signal and ground terminals regardless of whether the terminals are positioned in wafers that are inserted into a housing or the terminals are inserted directly into a housing. In addition, if the signal terminals are configured as differential pairs, they may be broad-side or edge coupled. Also, there are many possible variations in the materials and configurations. For example, components that are formed of metal may be formed of plated plastic provided that the necessary mechanical and electrical characteristics of the components are maintained. These modifications and/or combinations fall within the art to which this invention relates and are intended to be within the scope of the claims, which follow. It is noted, as is conventional, the use of a singular element in a claim is intended to cover one or more of such an element.

**CLAIMS**

1. A connector, comprising:  
a housing;  
a first wafer positioned in the housing and supporting a first ground terminal;  
a second wafer positioned in the housing and supporting a second ground terminal;  
a third and fourth wafer positioned between the first and second wafers, the third and fourth wafer each supporting a signal terminal, the signal terminals defining a differential pair, the differential pair positioned between the first and second ground terminals; and  
a bridge extending between the first ground terminal and the second ground terminal, the bridge electrically connecting the first and second ground terminal and electrically insulated from the signal terminals, the bridge configured to provide the first and second ground terminals with an maximum effective electrical length.
2. The connector of claim 1, wherein the bridge is a conductive pin extending between the first wafer and the second wafer and passing through the third and fourth wafer.
3. The connector of claim 1, wherein the ground and signal terminals each have a body section and the body section of the ground terminals is wider than the body section of the signal terminals where the bridge is positioned.
4. The connector of claim 1, wherein the maximum effective electrical length of the ground terminals is less than about 38 picoseconds.
5. The connector of claim 1, wherein the maximum effective electrical length of the ground terminals is less than about 26 picoseconds.
6. The connector of claim 1, further comprising a fifth wafers that supports a ground terminal, wherein the bridge electrically couples the ground terminal in the first, second and fifth wafer.

7. The connector of claim 1, wherein the bridge is a first bridge, the connector further comprising a second bridge coupling the first and second ground terminal, the first and second bridge spaced apart so as to provide the ground terminals with a desired electrical length between the first and second bridge.

8. The connector of claim 1, wherein the bridge comprises a clip supported by each of the wafers, the clip in electrical contact with the ground terminal and electrically separated from the signal terminals.

9. An electrical connector comprising:  
a dielectric housing with a first and second sidewall;  
a pair of ground terminals positioned within the housing;  
a pair of signal terminals positioned within the housing between the ground terminals that make up the pair of ground terminals, wherein each terminal includes a contact section at one end configured for making an electrical connection to a mating component, a tail at an opposite end, and a body section positioned between the contact section and the tail, the contact sections of the pair of ground terminals and the pair of signal terminals forming a row of contacts sections in a ground, signal, signal, ground configuration; and  
a bridge electrically connecting the pair of ground terminals together, the bridge extending transversely to the signal terminals.

10. The electrical connector of claim 9, wherein the bridge is selected from group consisting of a conductive pin and a plurality of conductive clips.

11. The electrical connector of claim 10, wherein the bridge is the conductive pin and the conductive pin extends through the first sidewall.

12. The electrical connector of claim 9, wherein the pair of ground terminals is a first pair of ground terminals, the connector further including a second pair of ground terminals, the bridge electrically coupling the first and second pair of ground terminals.

13. The electrical connector of claim 12, wherein the first pair of ground terminals includes a first ground terminal and a second ground terminal and the second ground pair comprises the second ground terminal and a third ground terminal.

14. The electrical connector of claim 13, wherein the bridge electrically interconnects the first, second and third ground terminal.

15. The electrical connector of claim 9, wherein each ground terminal includes a projection extending from the body section and the bridge engages the projection.

16. The electrical connector of claim 15, where one of the bridge and the projection includes a deflectable arm configured to engage the other.

17. The electrical connector of claim 9, wherein the body section of the pair of signal terminals has a first width at the point where the bridge extends transverse to the signal terminals and the body section of the pair of ground terminals has a second width at the point where the bridge is coupled to the ground terminals, the second width being greater than the first width.

18. The electrical connector of claim 9, further including a plurality of ground wafers and at least one signal wafer, each ground wafer supporting one of the ground terminals and the at least one signal wafer supporting the signal terminals, the ground and the at least one signal wafer arranged in a subassembly of wafers.

19. The electrical connector of claim 18, wherein the bridge extends through the at least one signal wafer positioned between adjacent ground wafers.

20. The electrical connector of claim 18, wherein the bridge is a first bridge, the connector further comprising a second bridge, the second bridge extending through the ground wafers to electrically connect the ground terminals within adjacent ground wafers, the combination of the first and second bridge causing a maximum effective electrical length of the ground terminals to be shorter than if just the first bridge were used.

21. The electrical connector of claim 9, further including a light pipe configured to direct light toward a mating face of the connector.

22. The electrical connector of claim 9, wherein the connector includes a first opening having ground members and signal terminals adjacent thereto and forming a first mating plane, the first opening configured to receive a portion of a first mating component, and a second opening having ground members and signal terminals adjacent thereto and forming a second mating plane, the second opening being configured to receiving a portion of a second mating component, the first and second mating planes being spaced apart and substantially parallel to each other.

23. The electrical connector of claim 9, wherein the pair of signal terminals is configured to provide a differential signal pair that is broad-side coupled.

24. An electrical connector comprising:  
a housing;  
a first and second ground wafer each support a plurality of ground terminals;  
a first and second signal wafer each supporting a plurality of signal wafers, the first and second signal wafer cooperatively providing a pair of differentially-coupled signal terminals, wherein the first and second ground wafer and the first and second signal wafer provide at least two rows of terminals; and  
a bridge extending through the first and second signal wafer and electrically connecting one of the ground terminals in the first ground wafer to one of the ground terminals in the second ground wafer, the bridge extending transversely to the differentially coupled signal terminals.

25. The electrical connector of claim 24, wherein the ground terminals electrically connected together by the bridge are configured to provide a maximum electrical length between discontinuities of not more than 33 picoseconds.

26. The electrical connector of claim 24, wherein the bridge is a first bridge, the connector comprising a plurality of additional bridges, the bridges configured to



provide a maximum electrical length between discontinuities of not more than 26 picoseconds.

27. A method of providing an electrical connector with a ground terminal having an electrical length less than a predetermined value, comprising:

providing a housing;

positioning a first, second and third wafer in the housing, the first wafer including a first ground terminal defining a first electrical path, the second wafer including a signal terminal and the third wafer including a second ground terminal defining a second electrical path; and

providing a bridge between the first and second ground terminals, the bridge shorting the first ground terminal to the second ground terminal so as to reduce an electrical length between impedance discontinuities in along the first and second ground members to less than a desired effective electrical length.

28. The method of claim 27, wherein the positioning comprises inserting a pin through the first, second and third wafer so as to engage the first and second ground terminal at a predetermined location while not extending transversely to but not contacting the signal terminal.

29. The method of claim 27, wherein the positioning of the first, second and third wafer in the housing couples clips in the first, second and third wafer so as to provide the bridge.

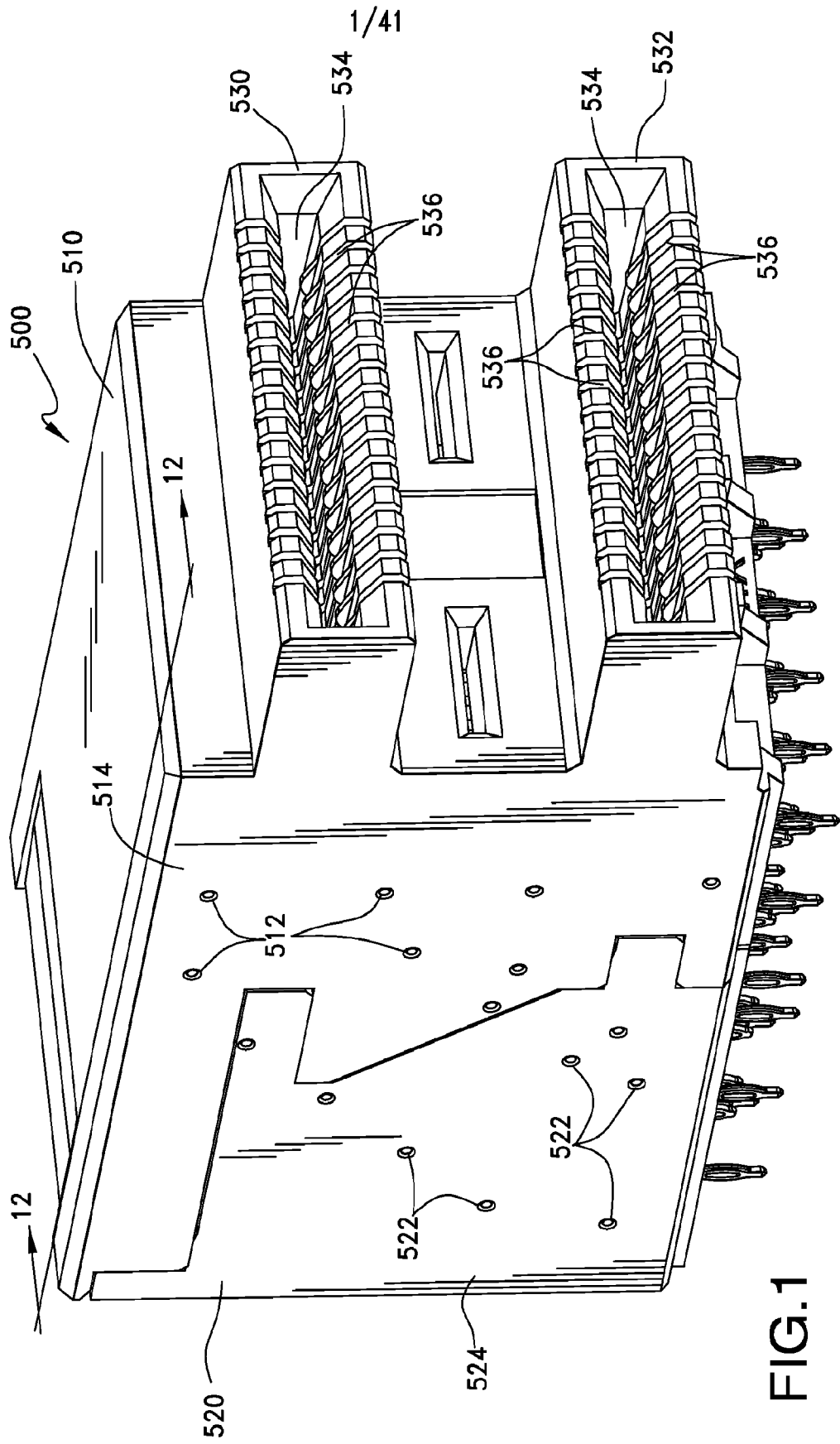


FIG. 1

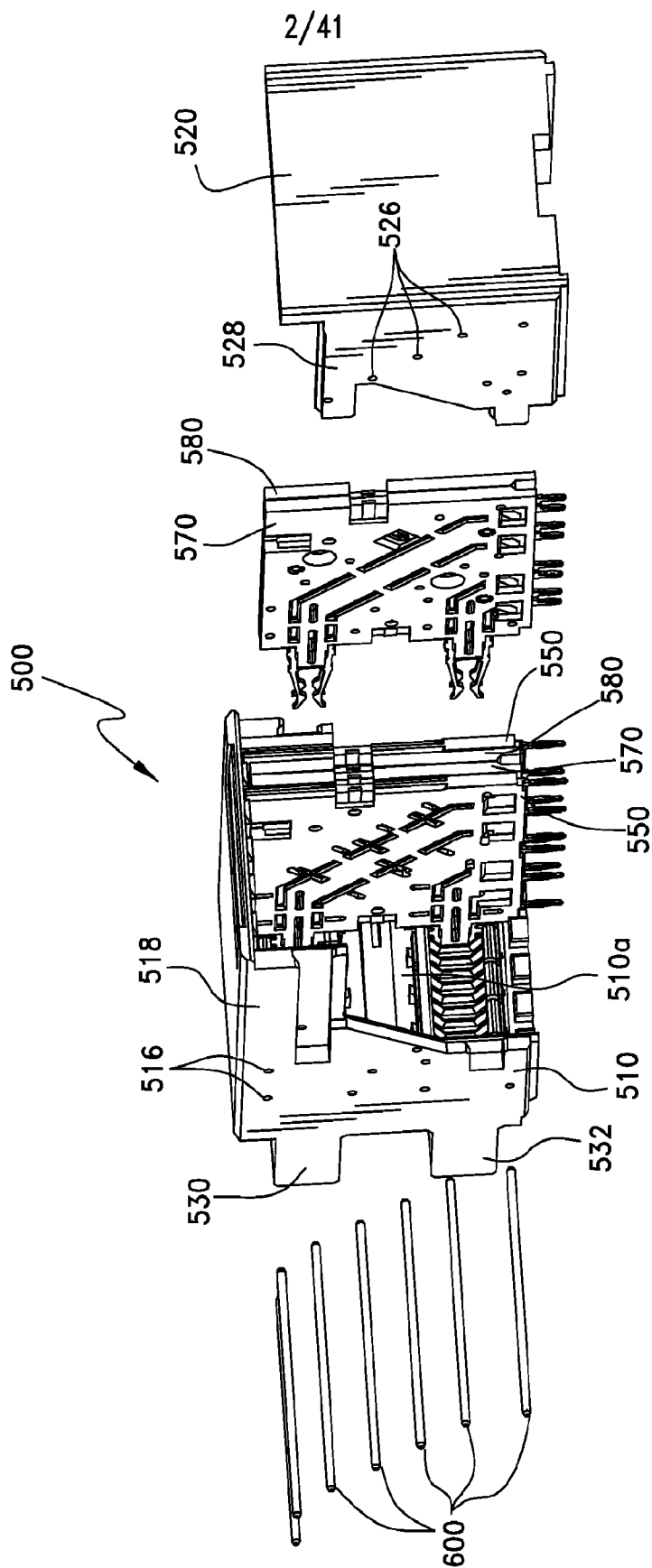
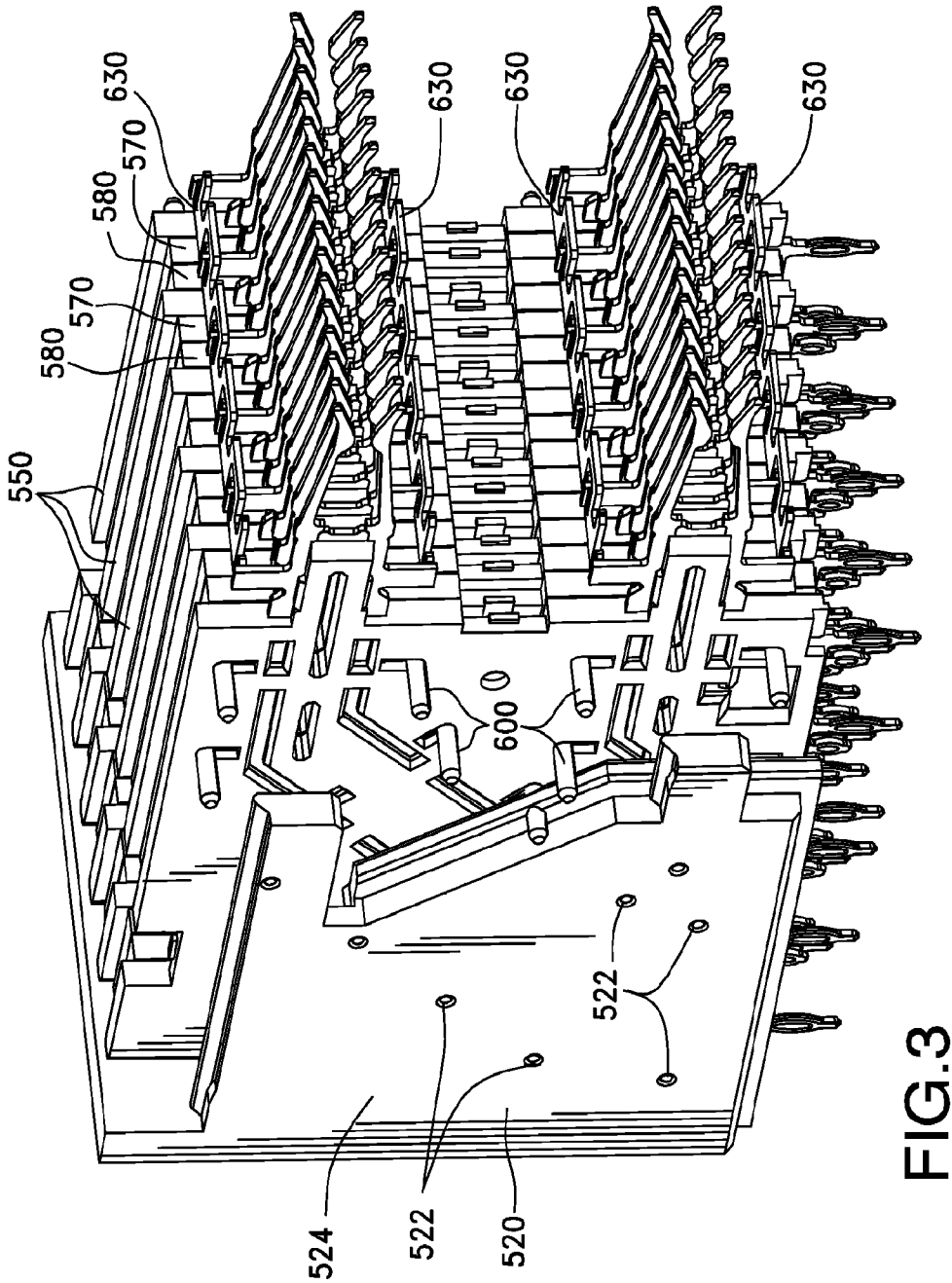


FIG. 2



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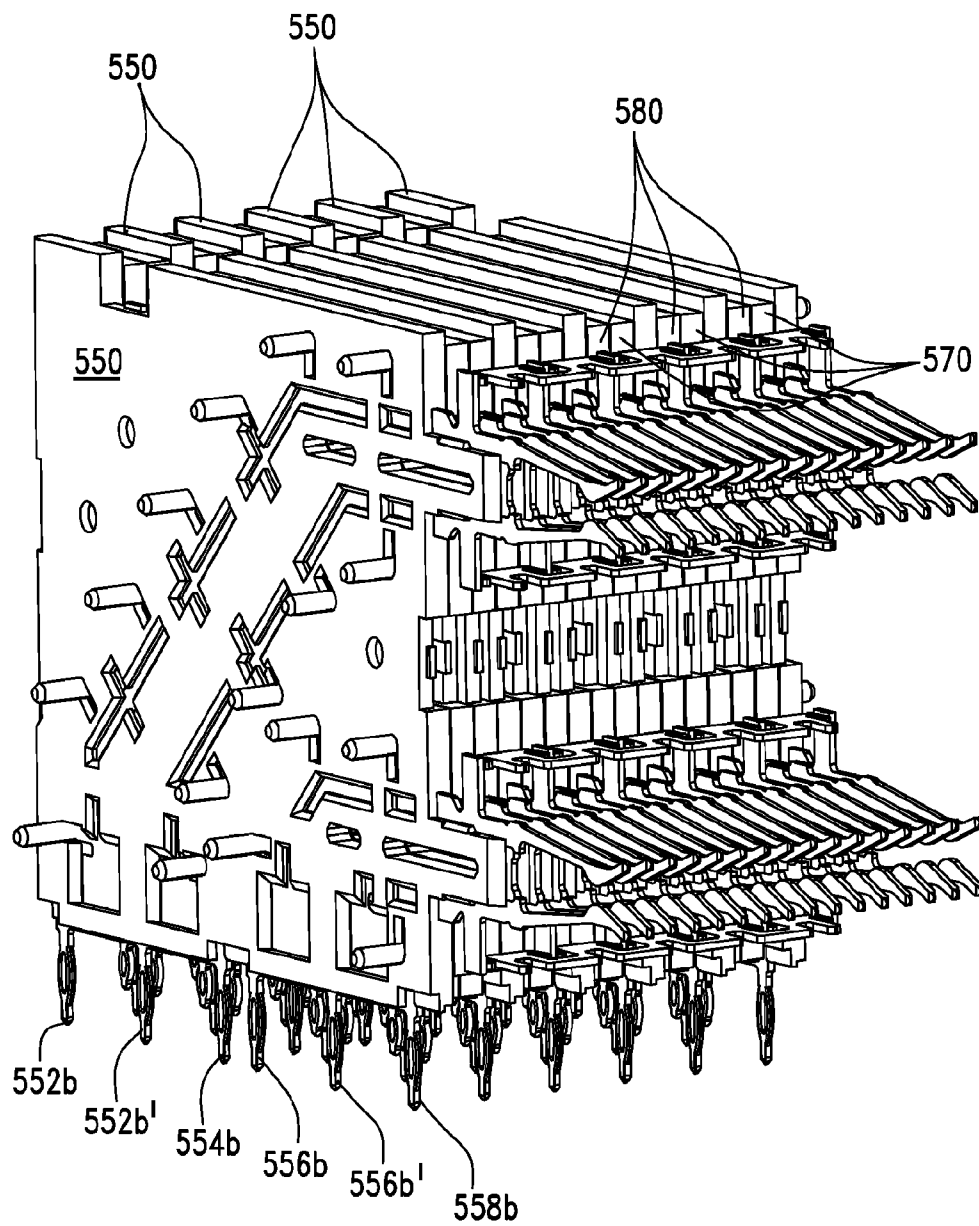
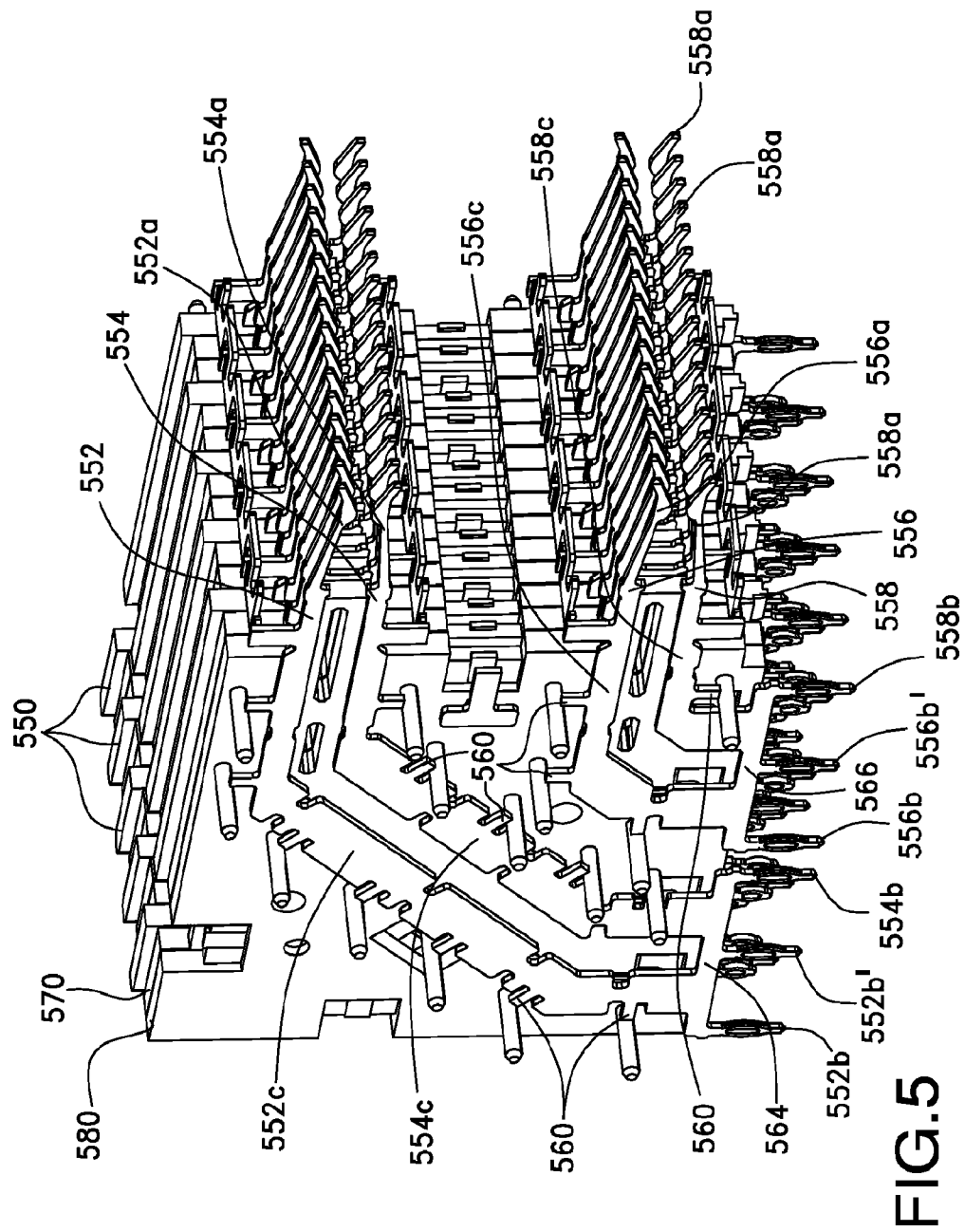


FIG.4

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**FIG. 5**

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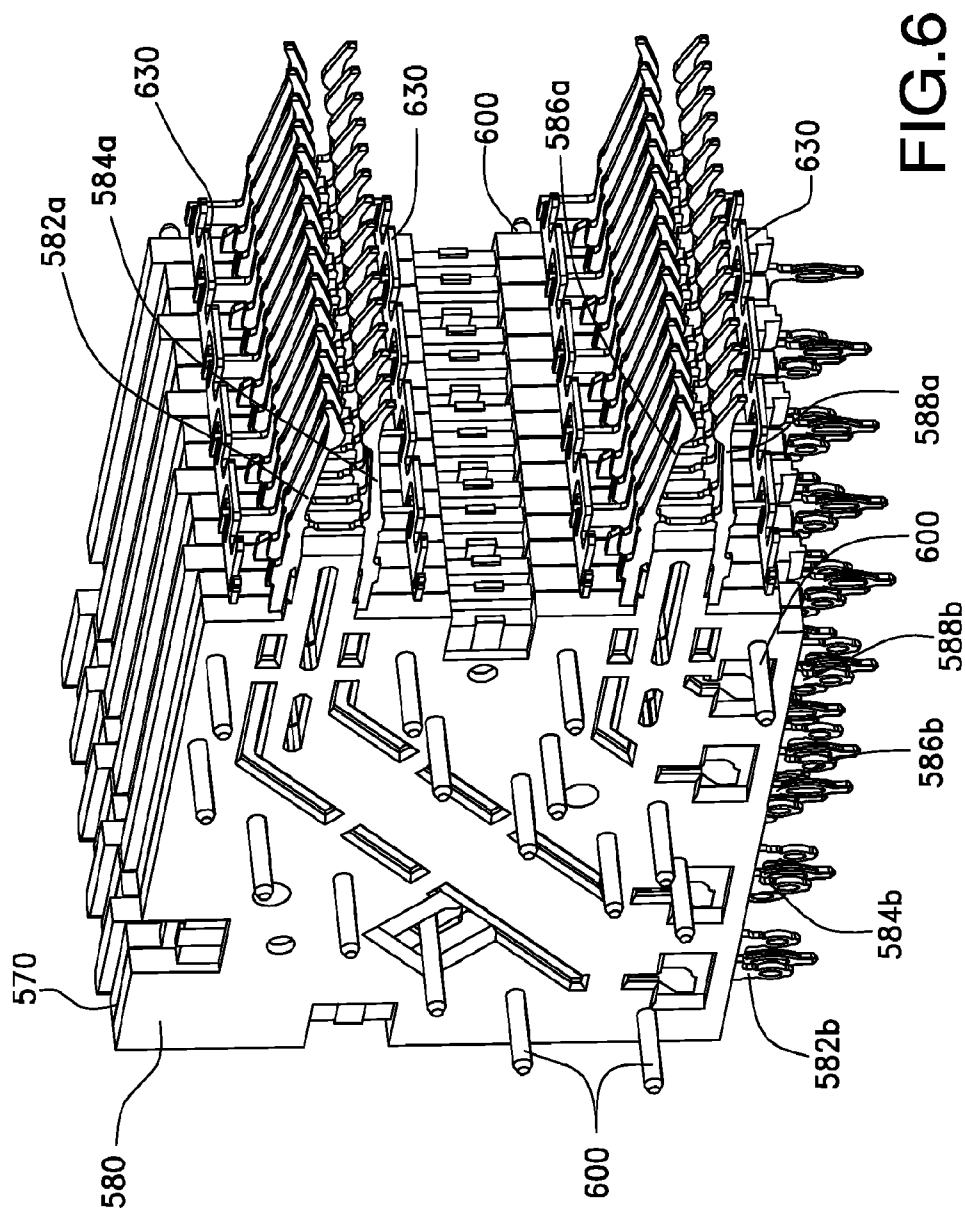


FIG. 6

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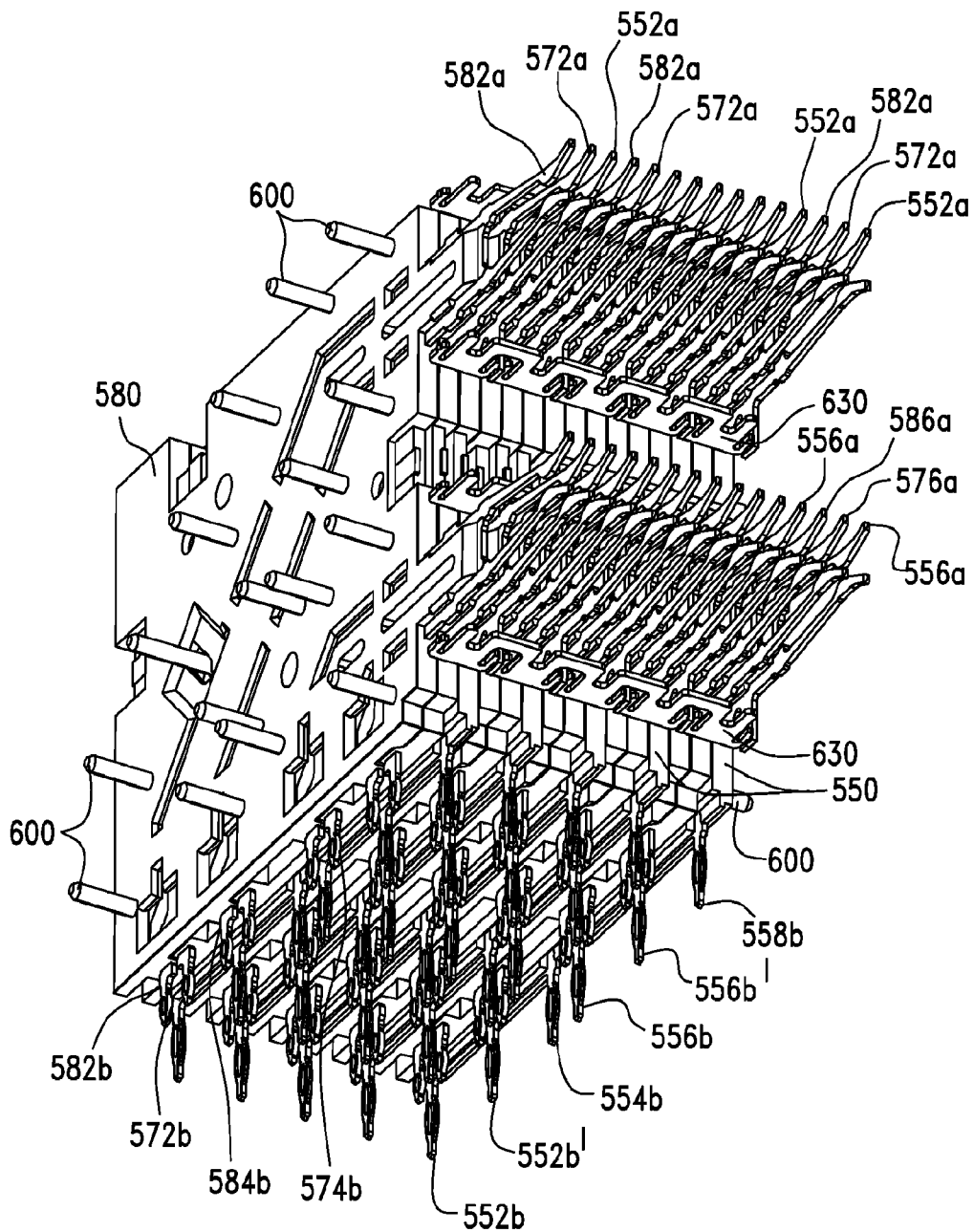


FIG.7



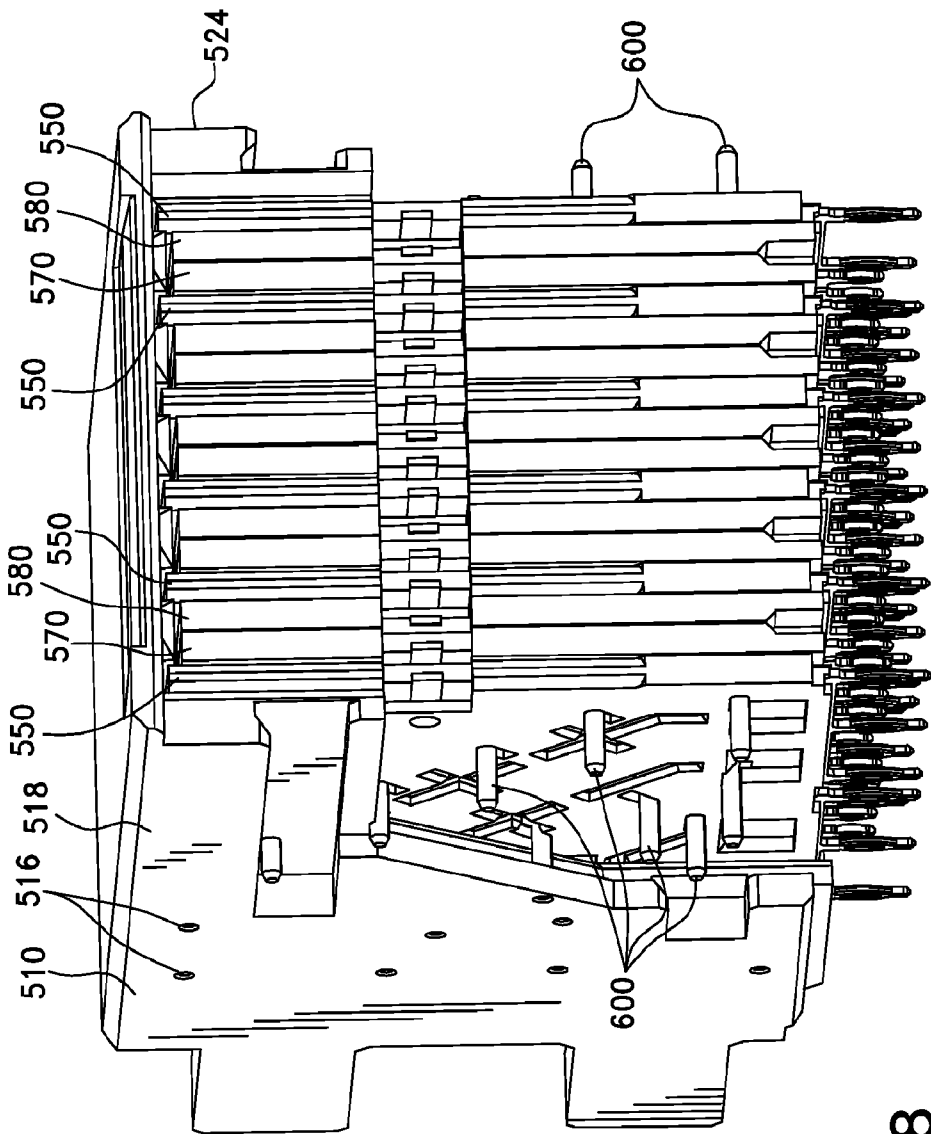
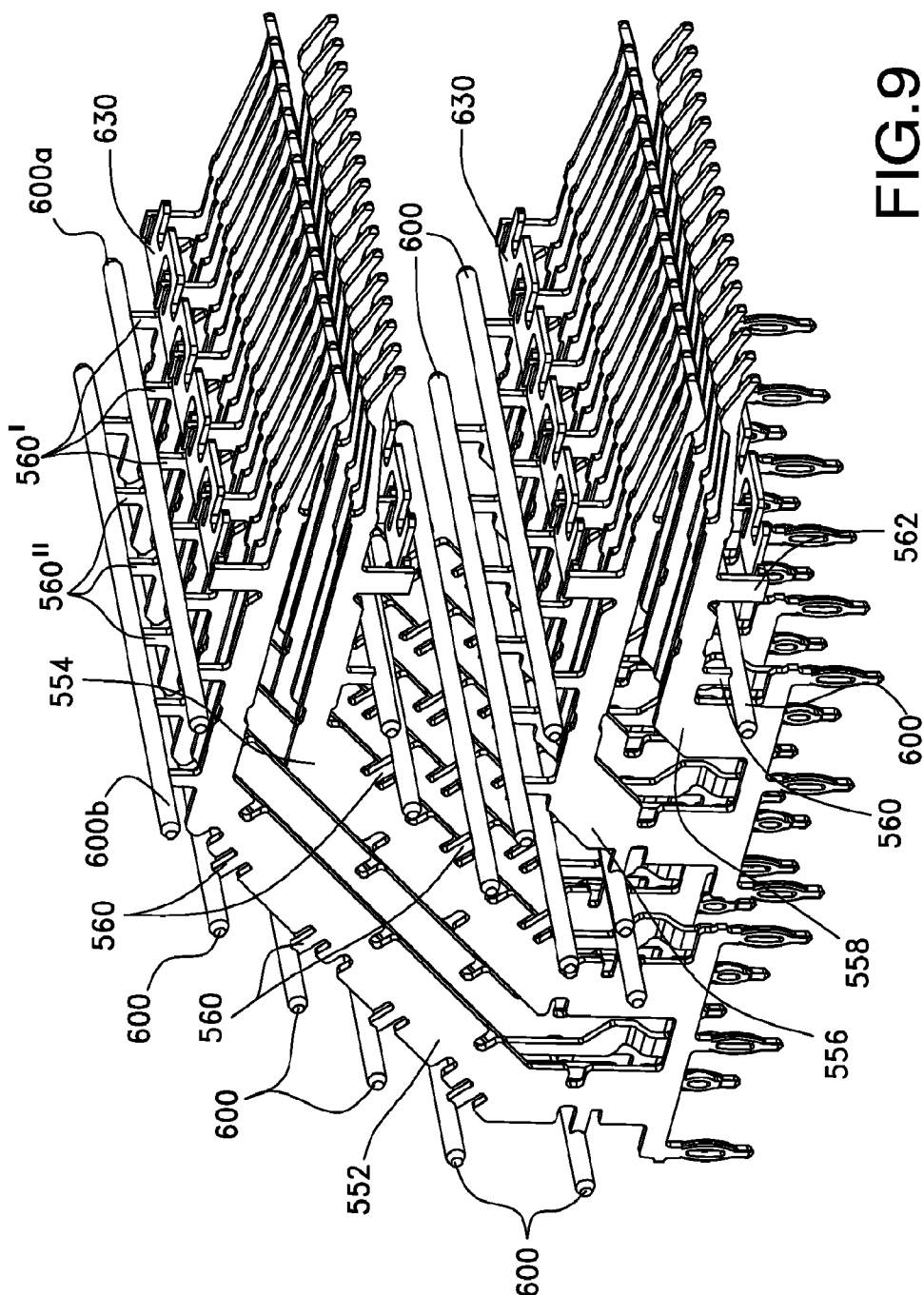


FIG.8

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**FIG. 9**

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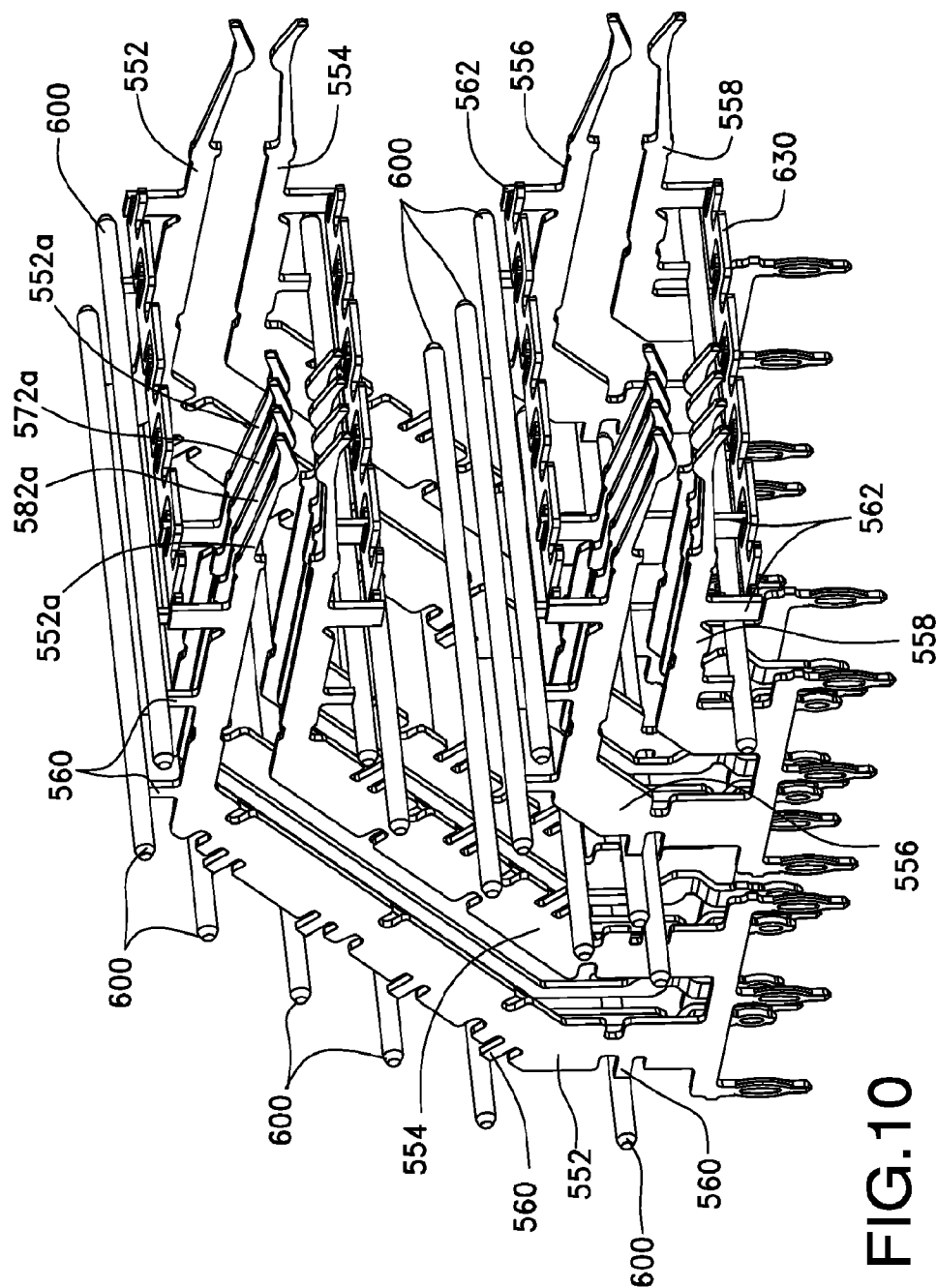


FIG. 10

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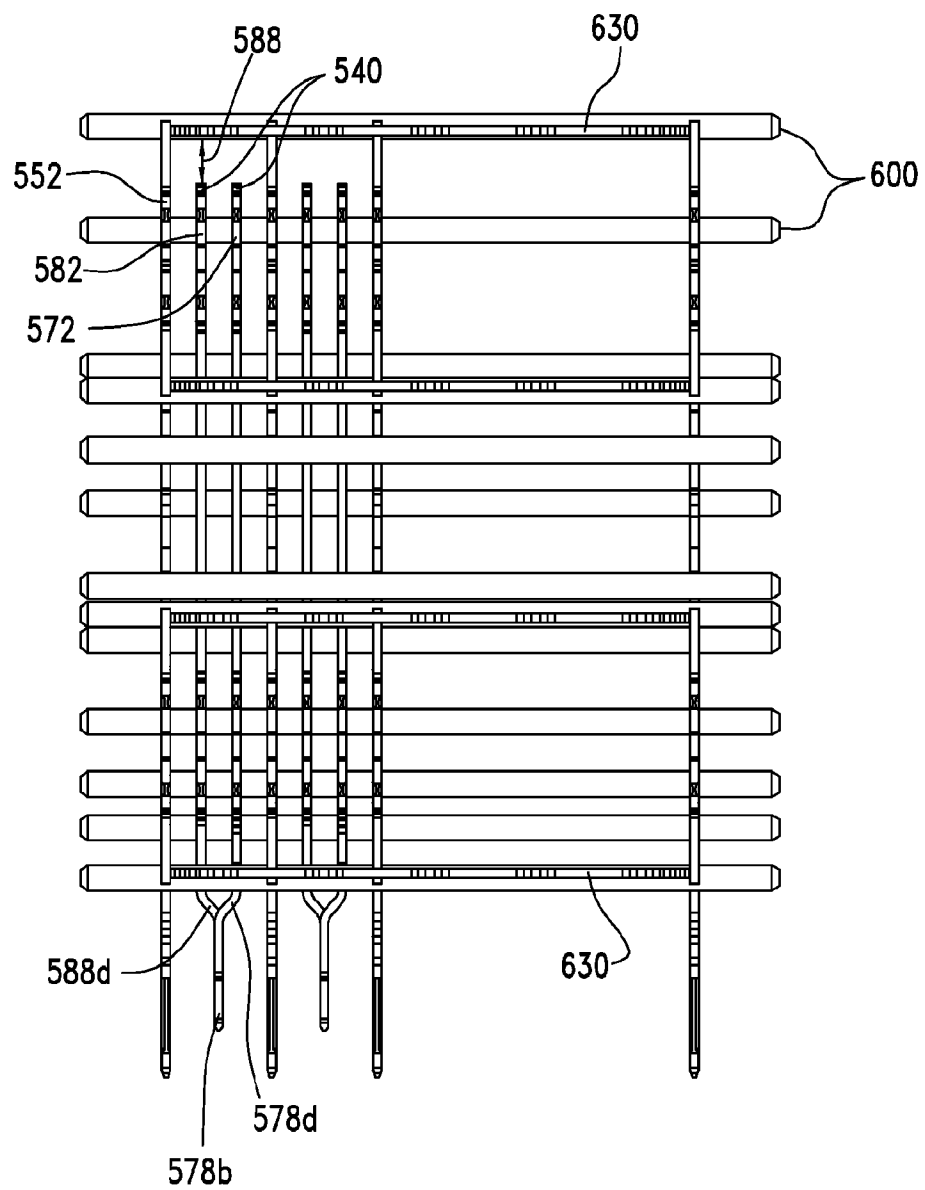


FIG.11

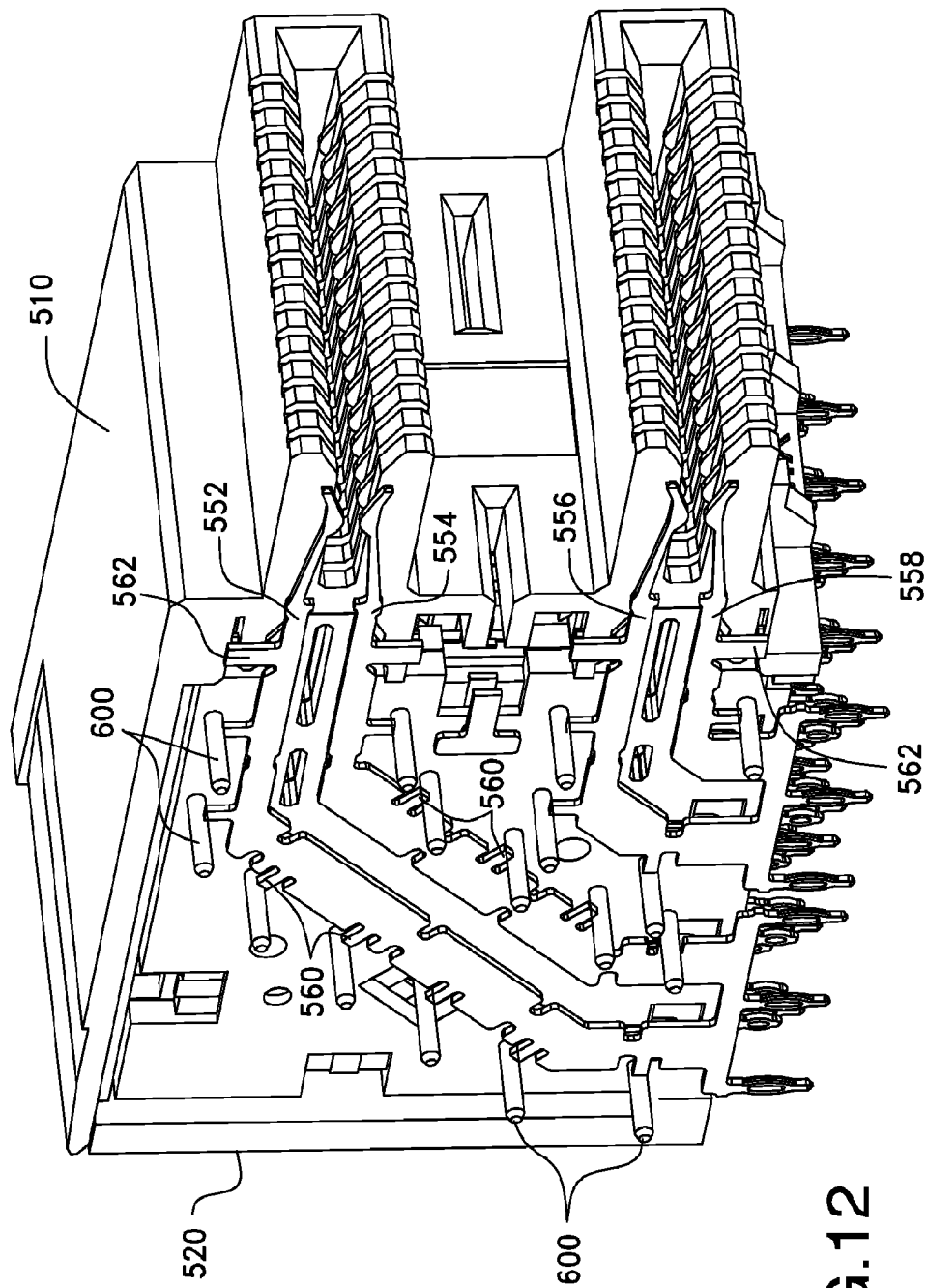


FIG.12

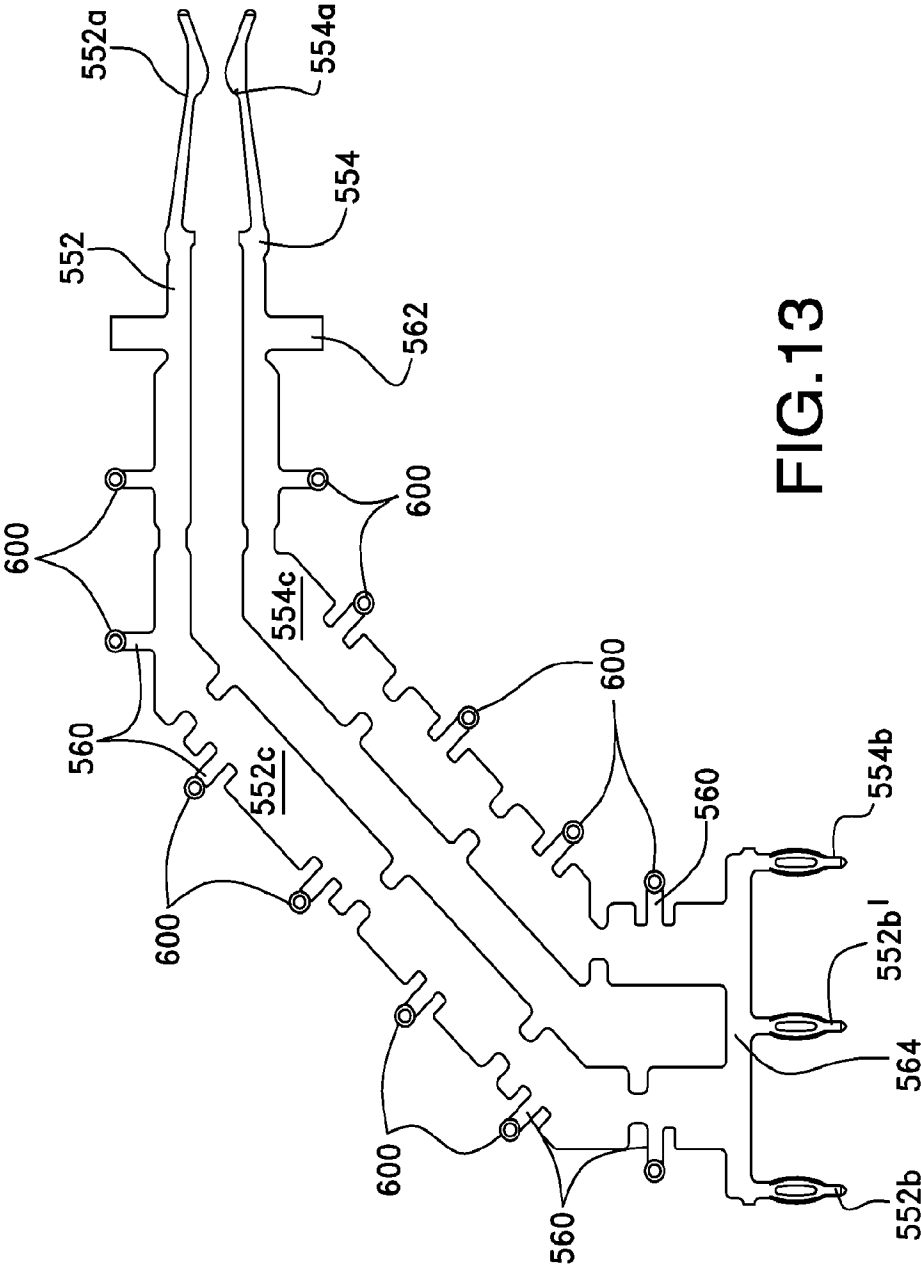
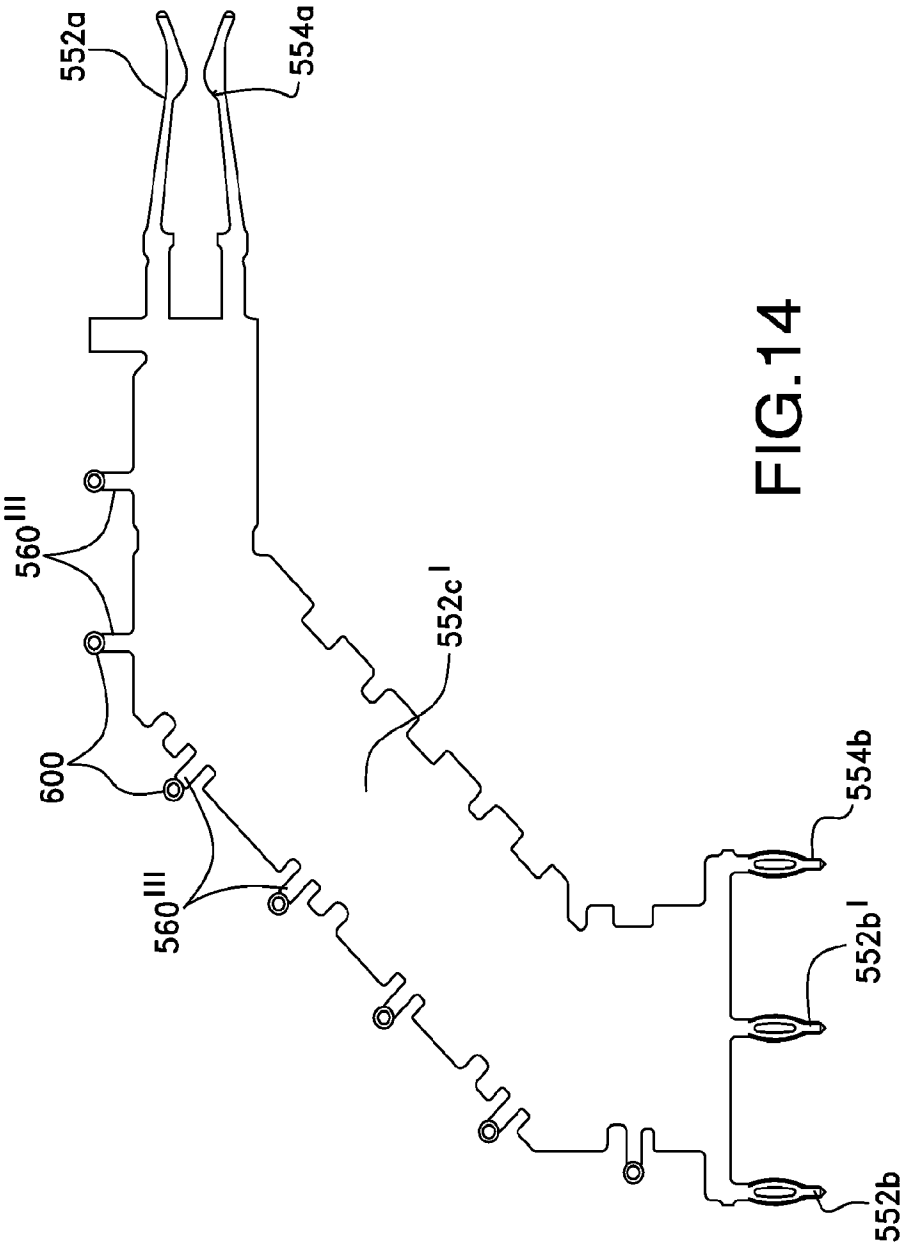


FIG.13



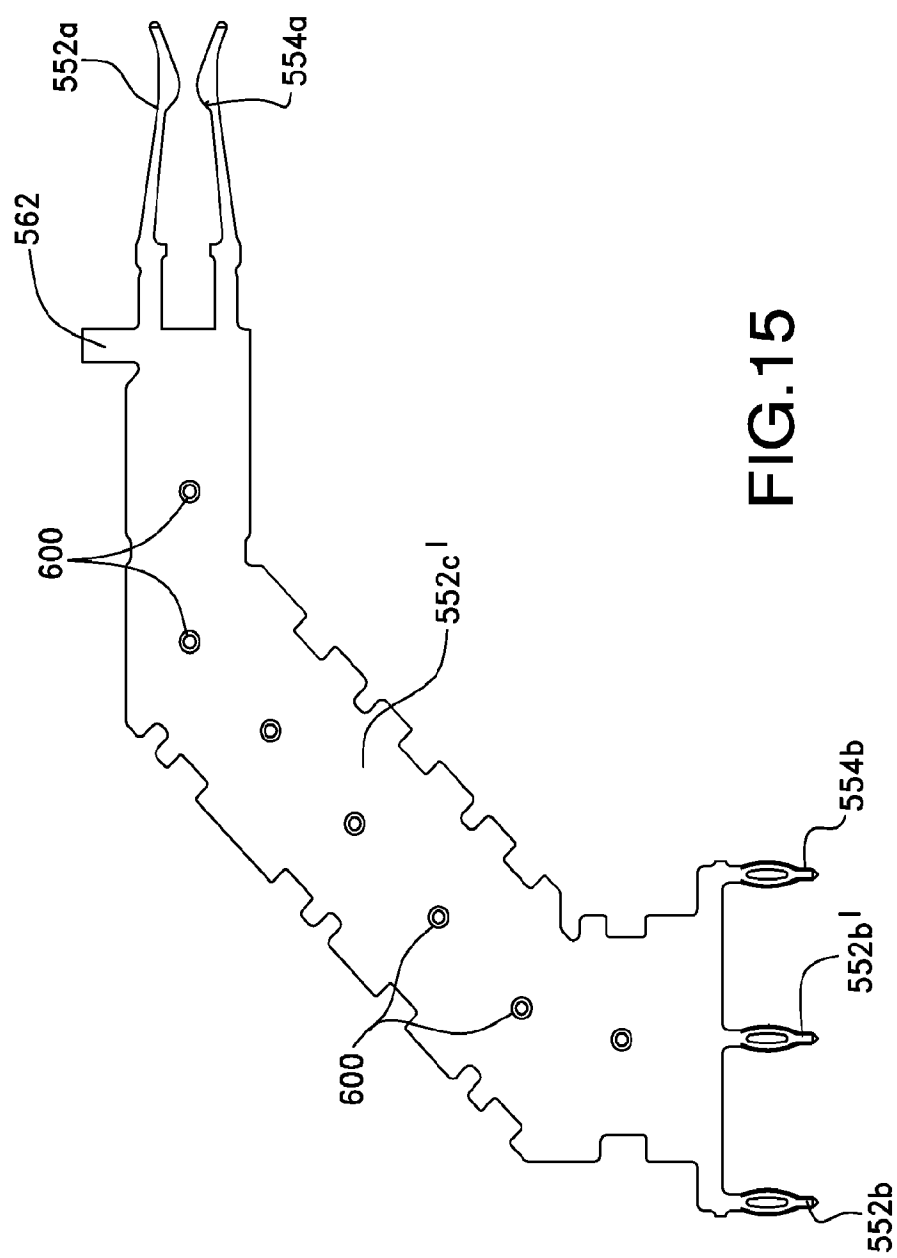


FIG.15



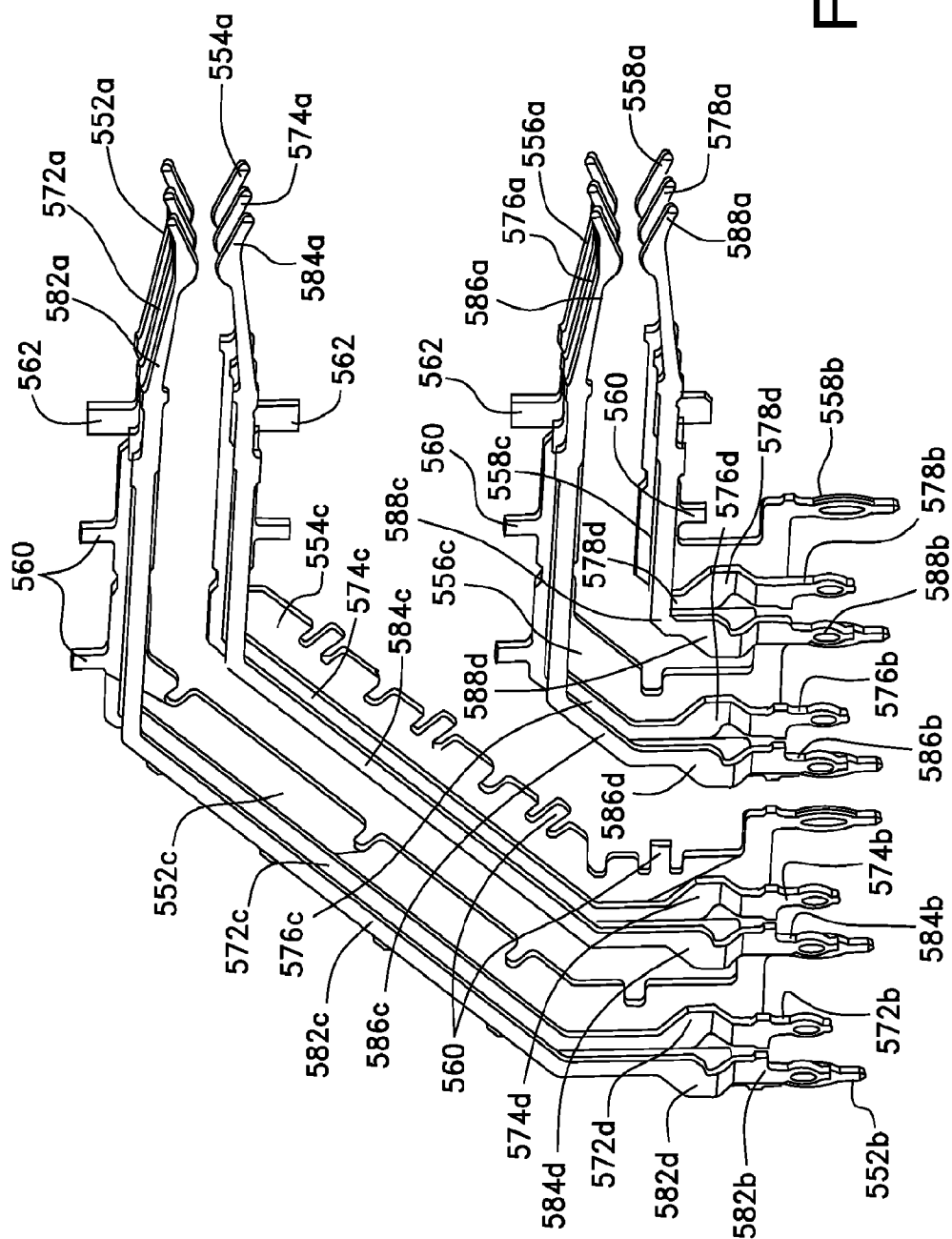


FIG. 16

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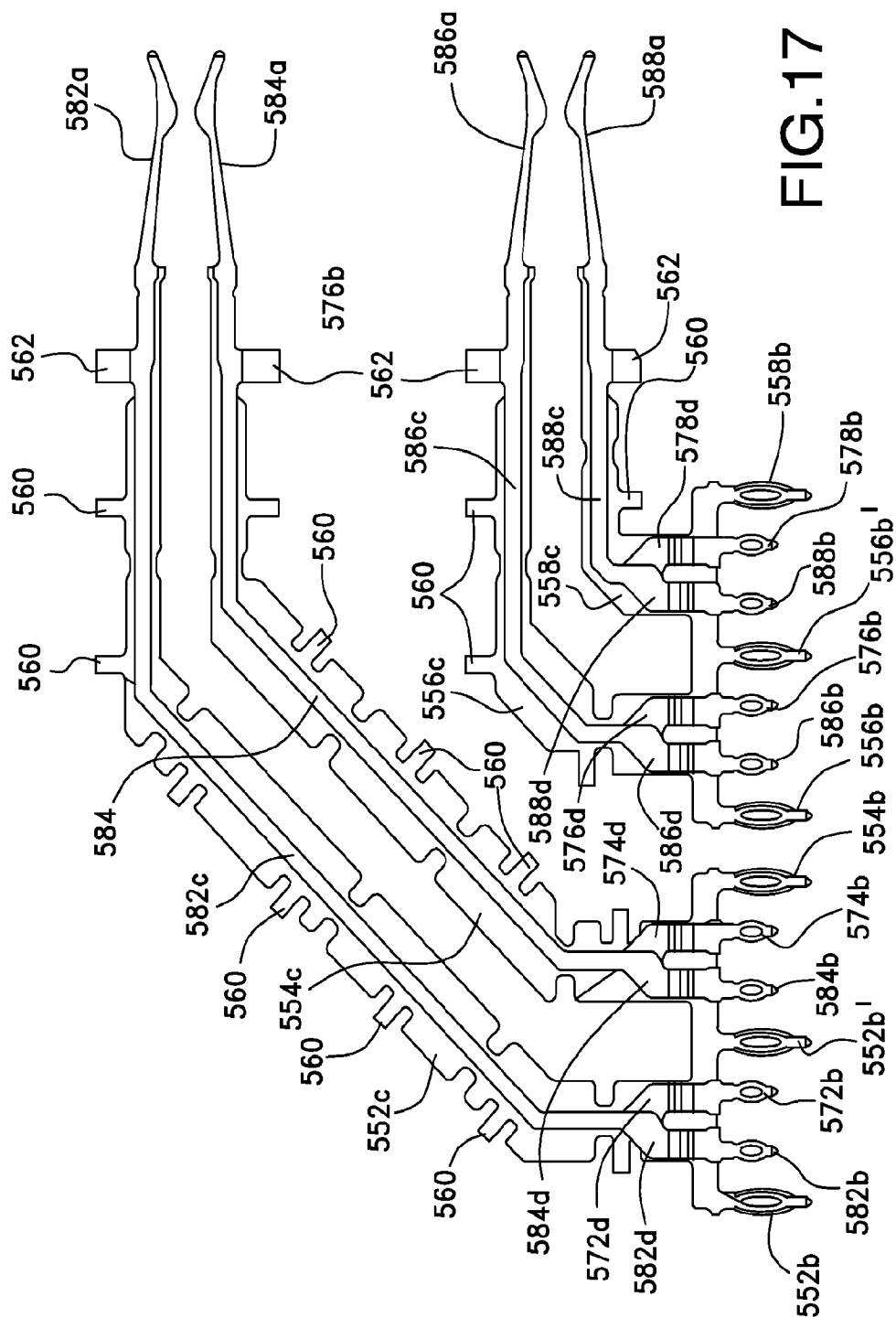


FIG. 17

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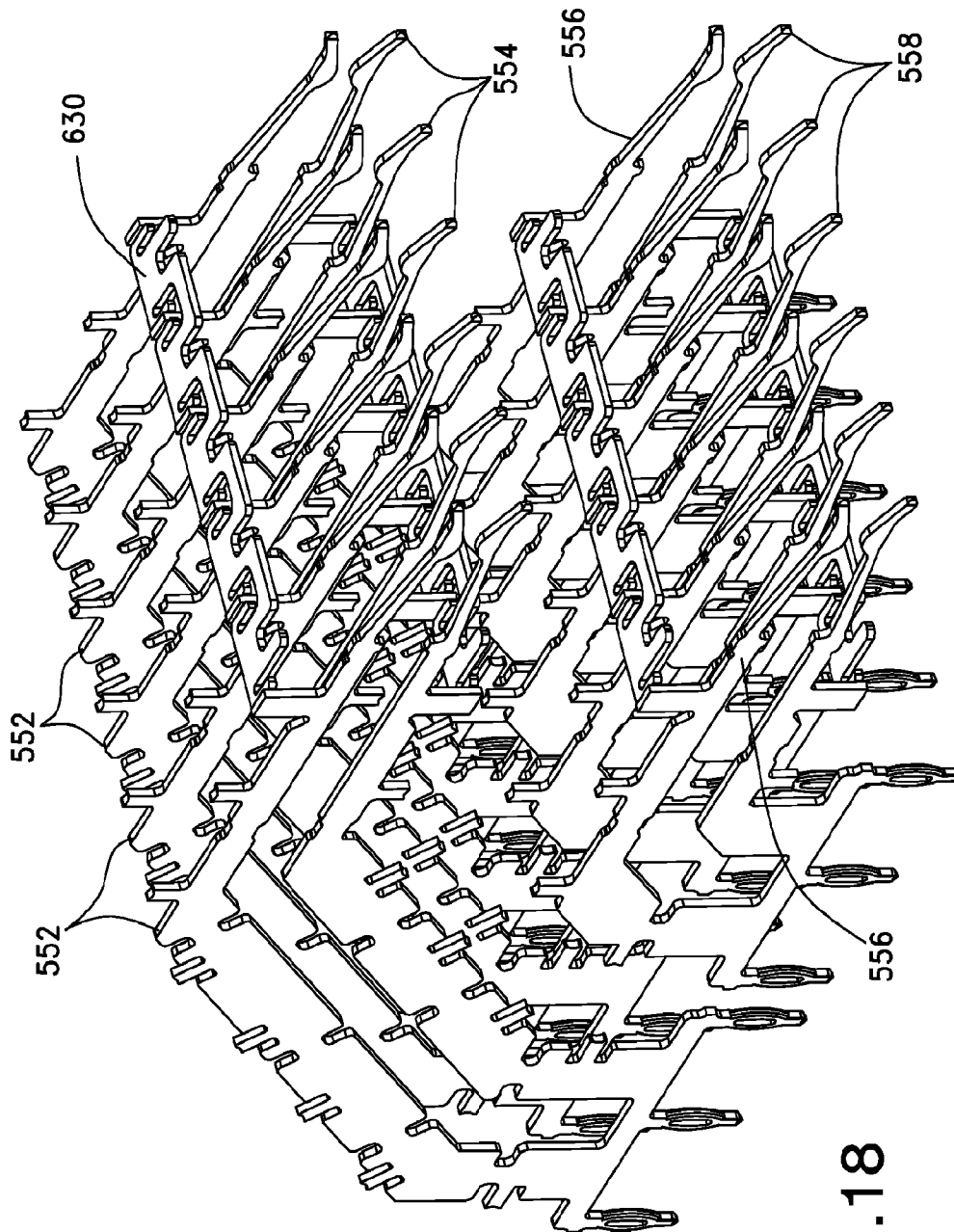


FIG.18

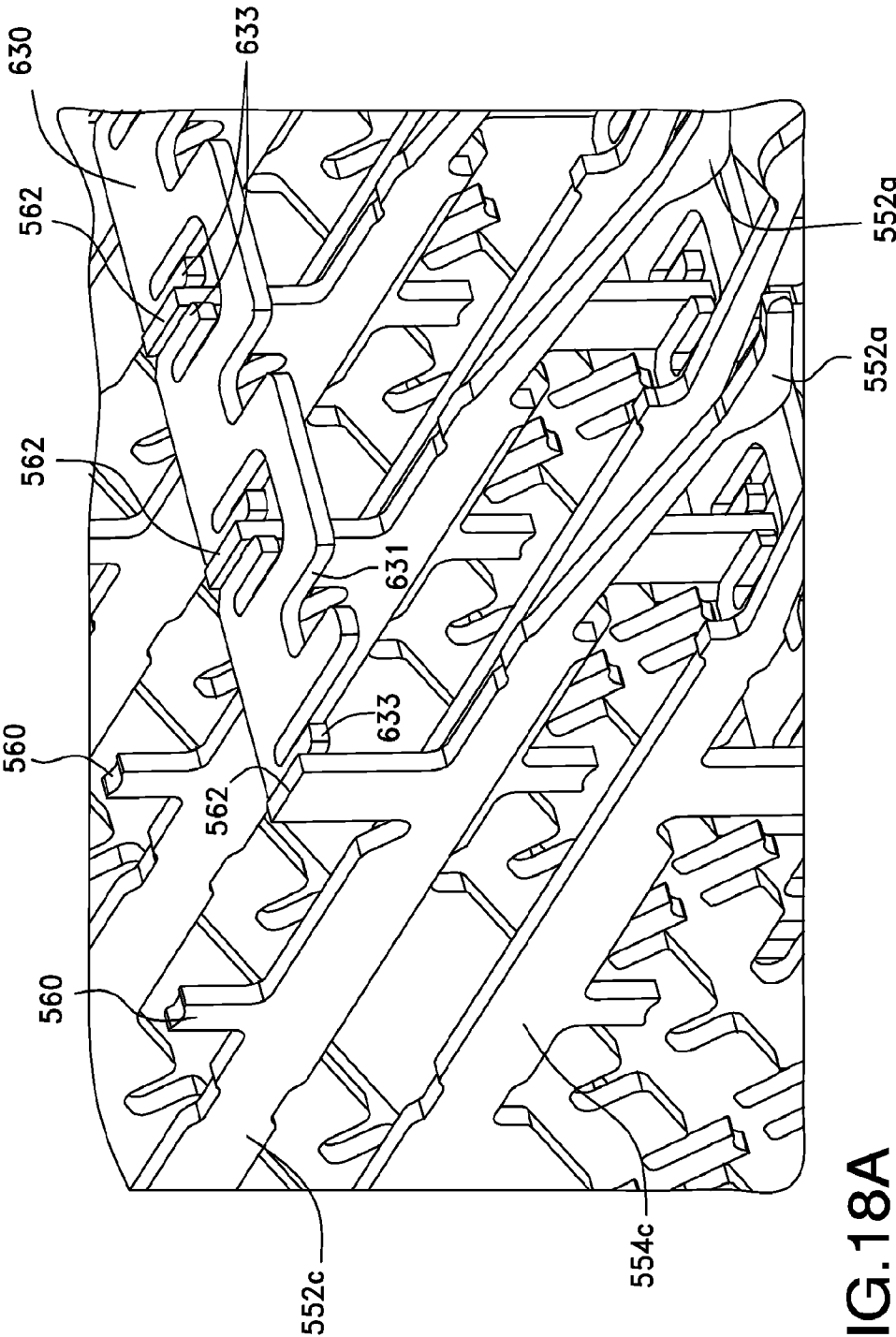


FIG. 18A

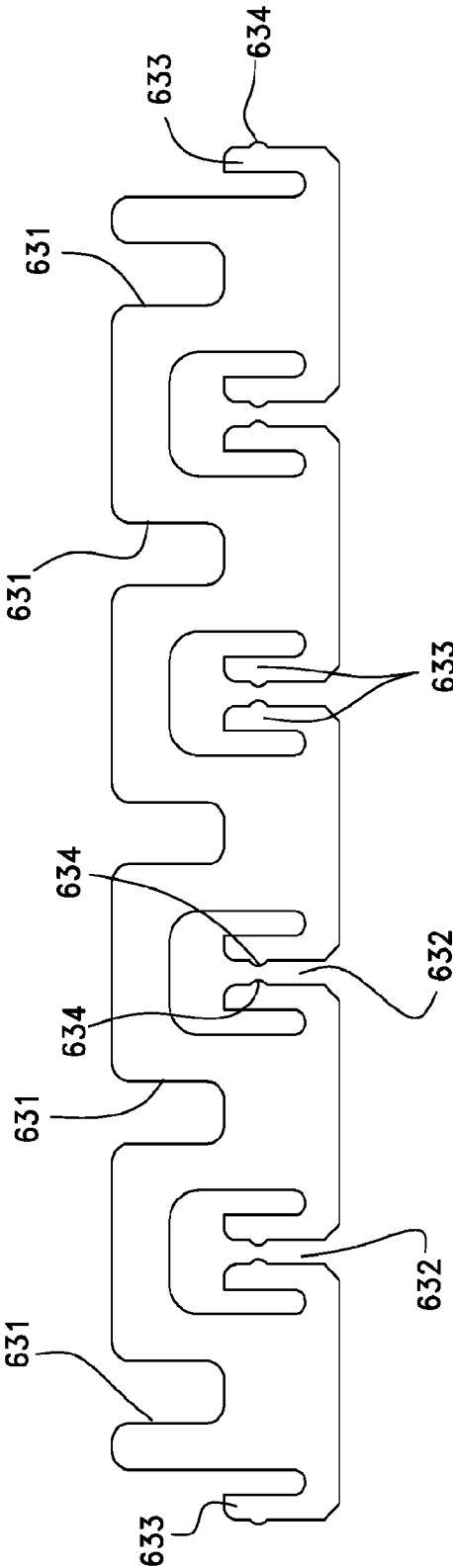


FIG.19

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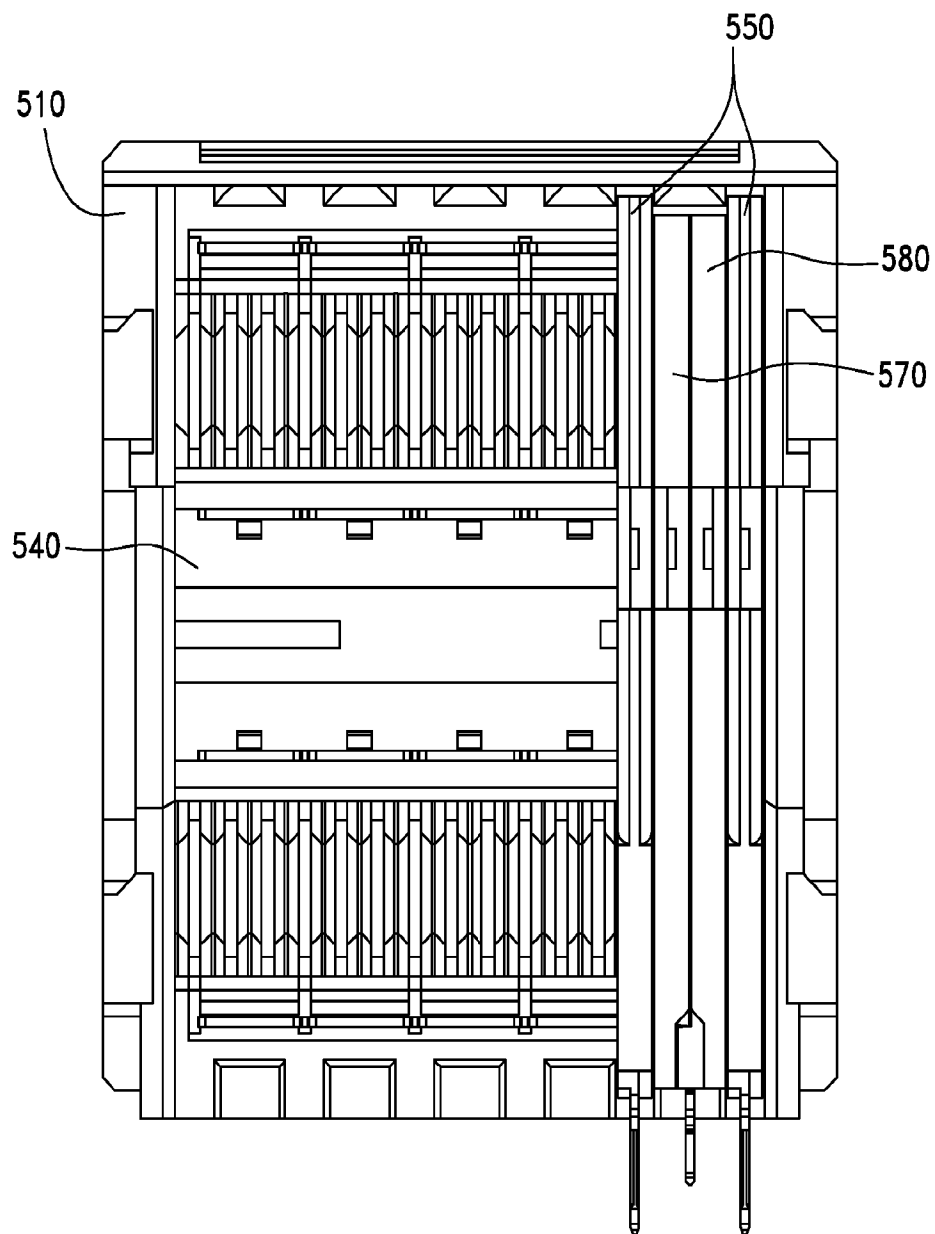


FIG.20

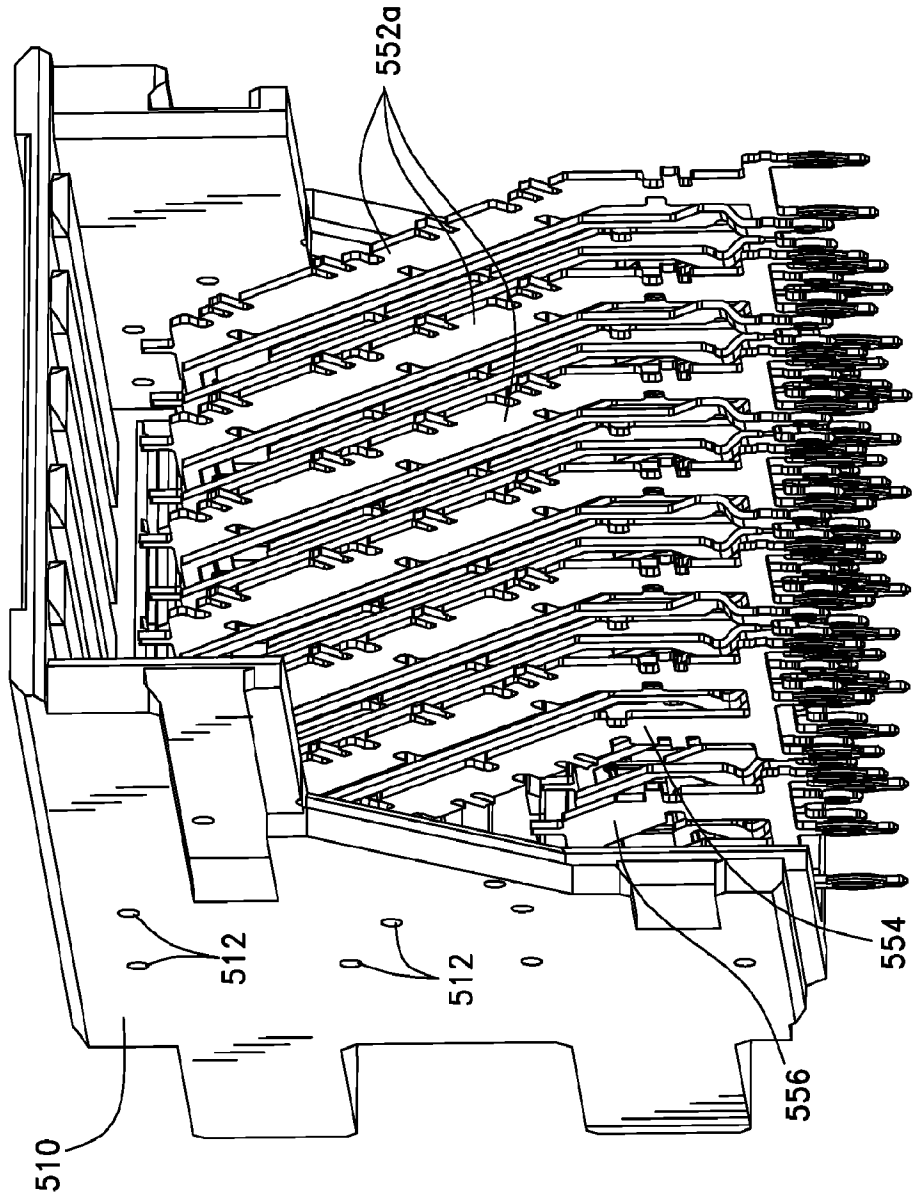


FIG.21

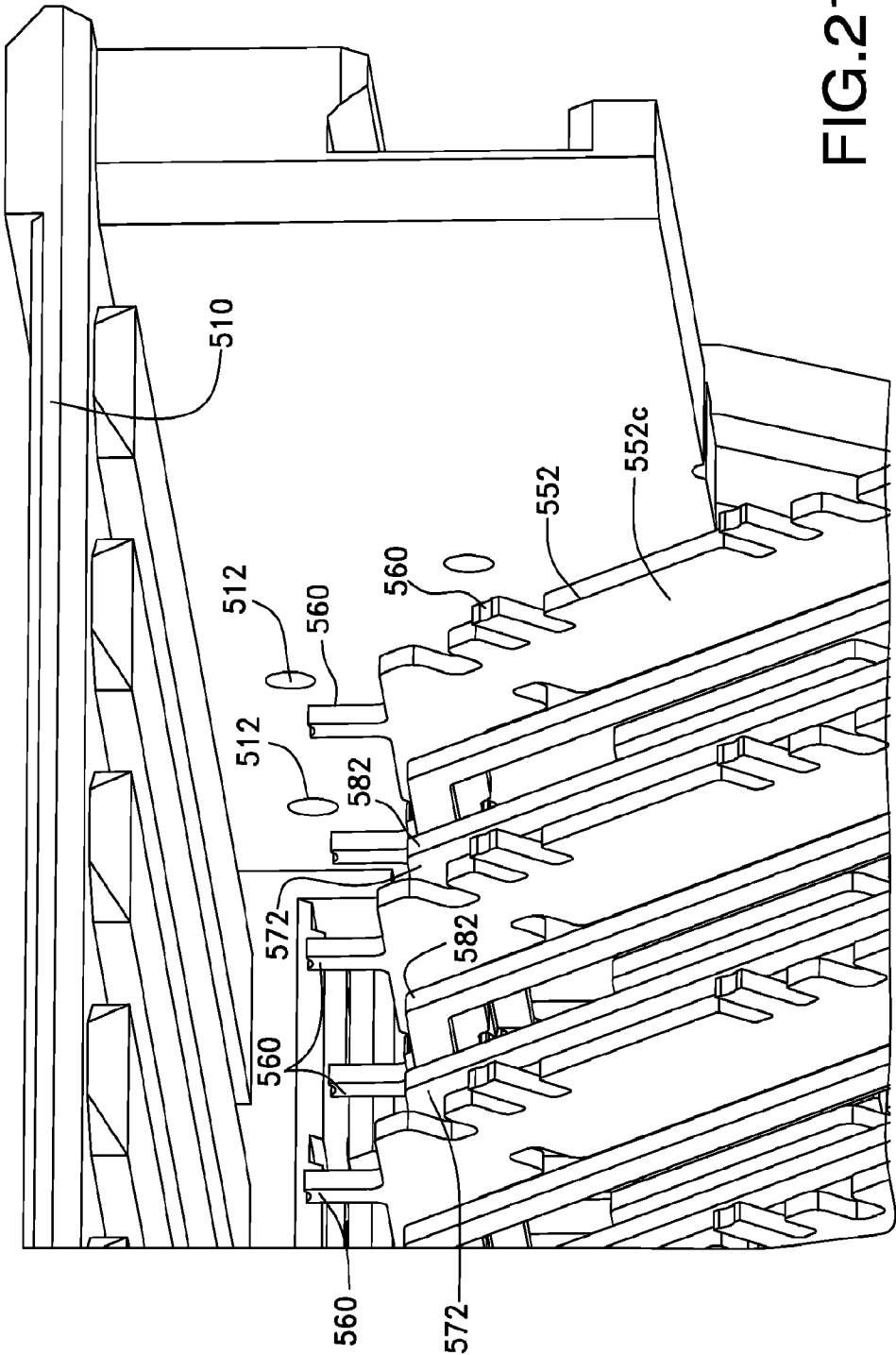
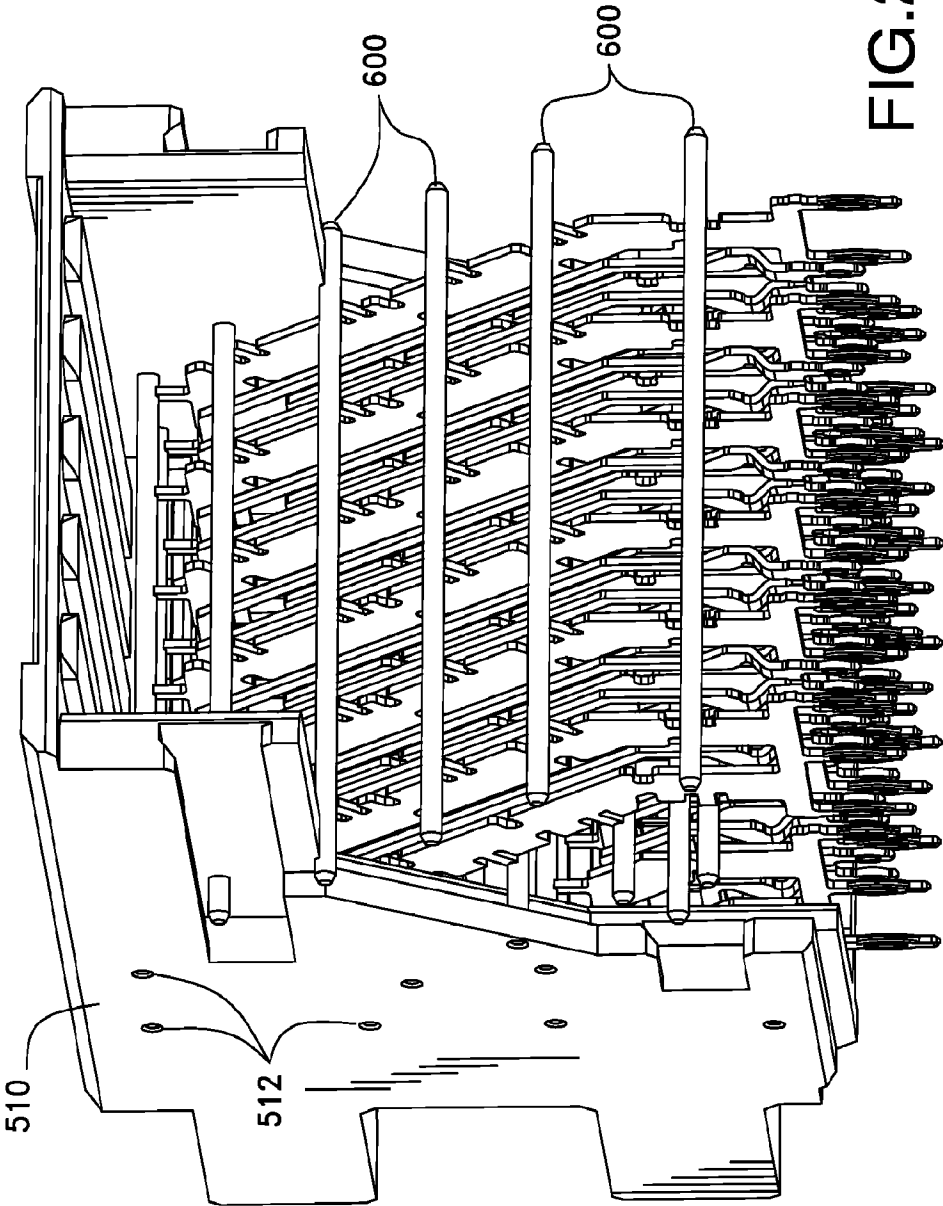


FIG. 21A





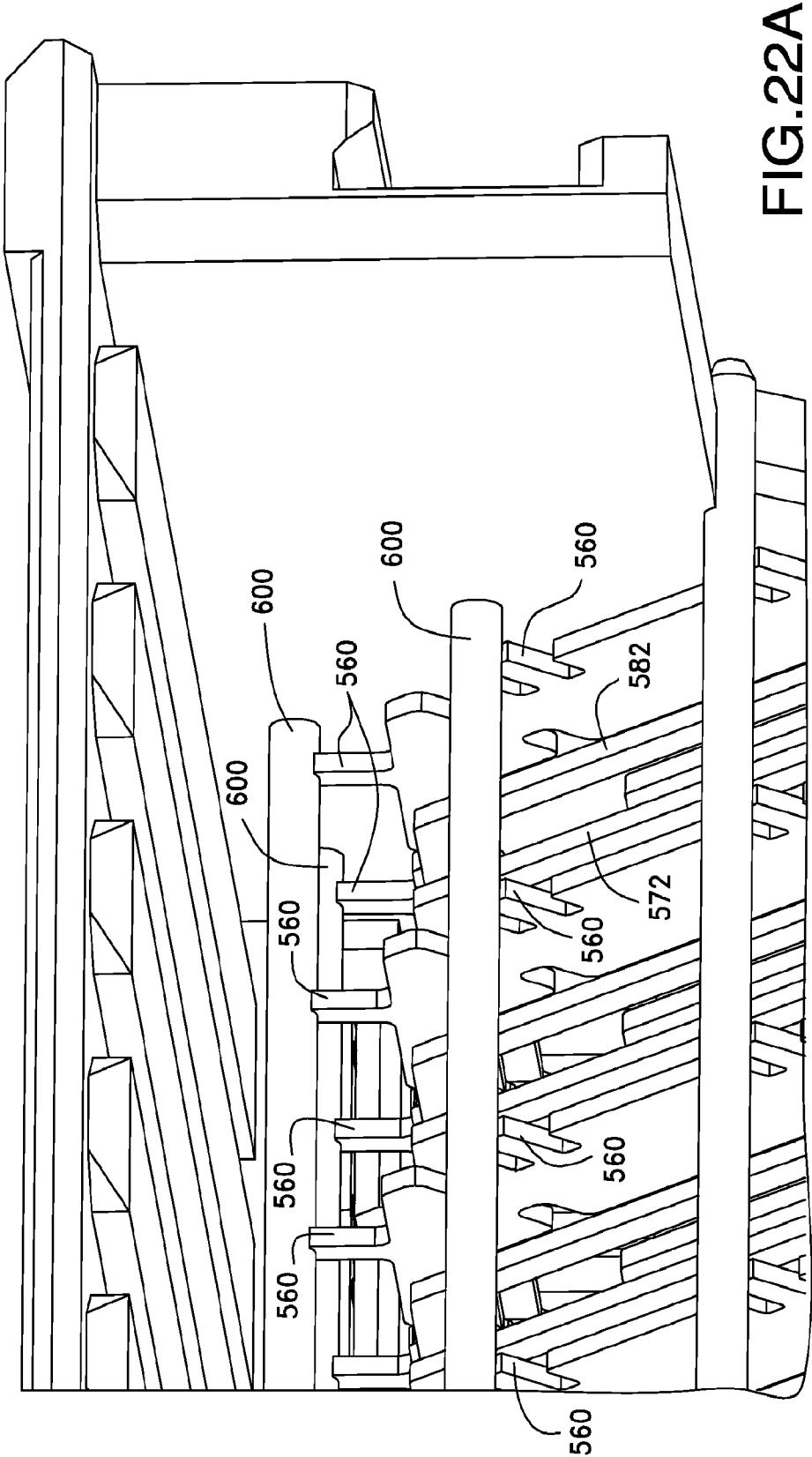
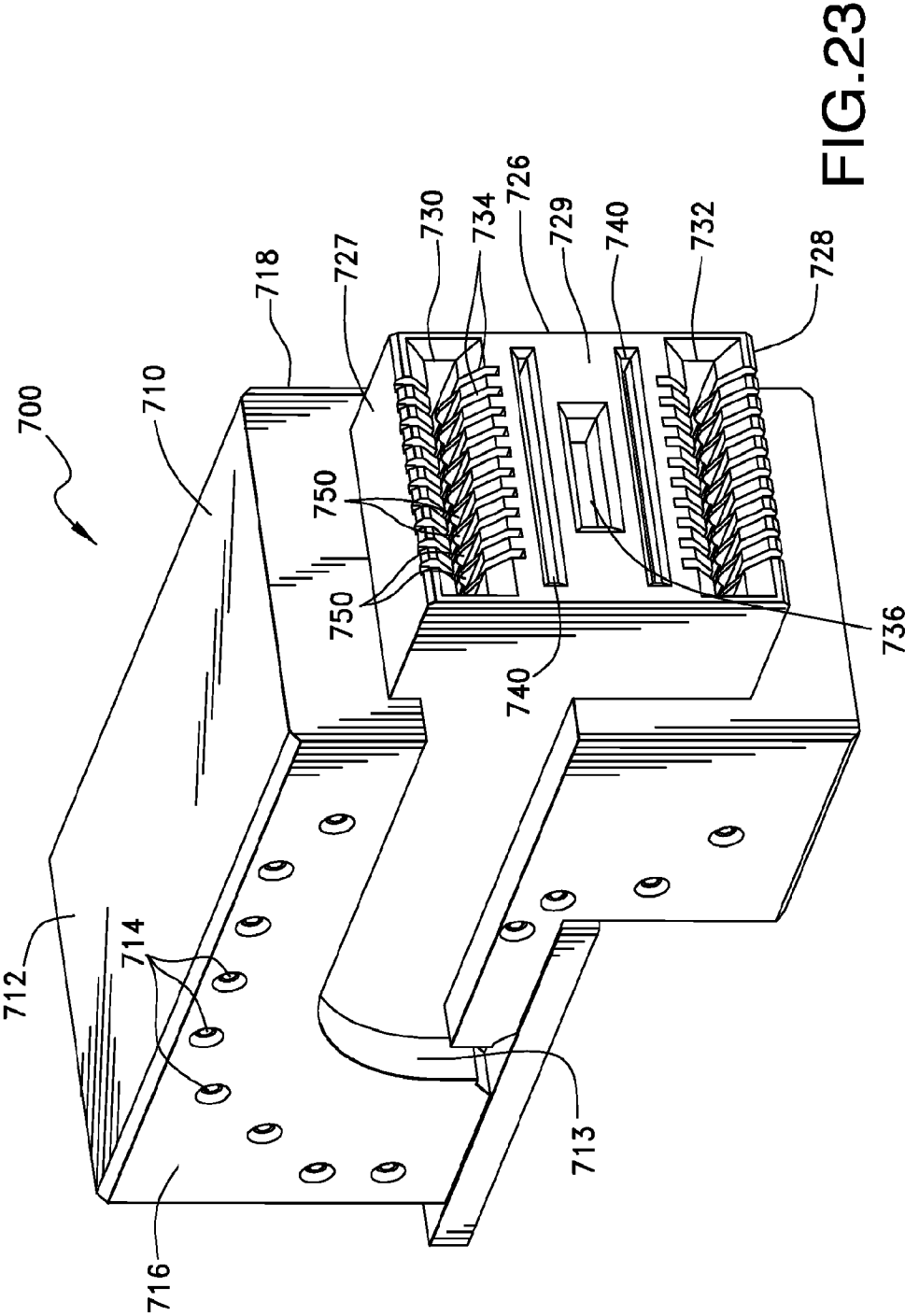


FIG. 22A



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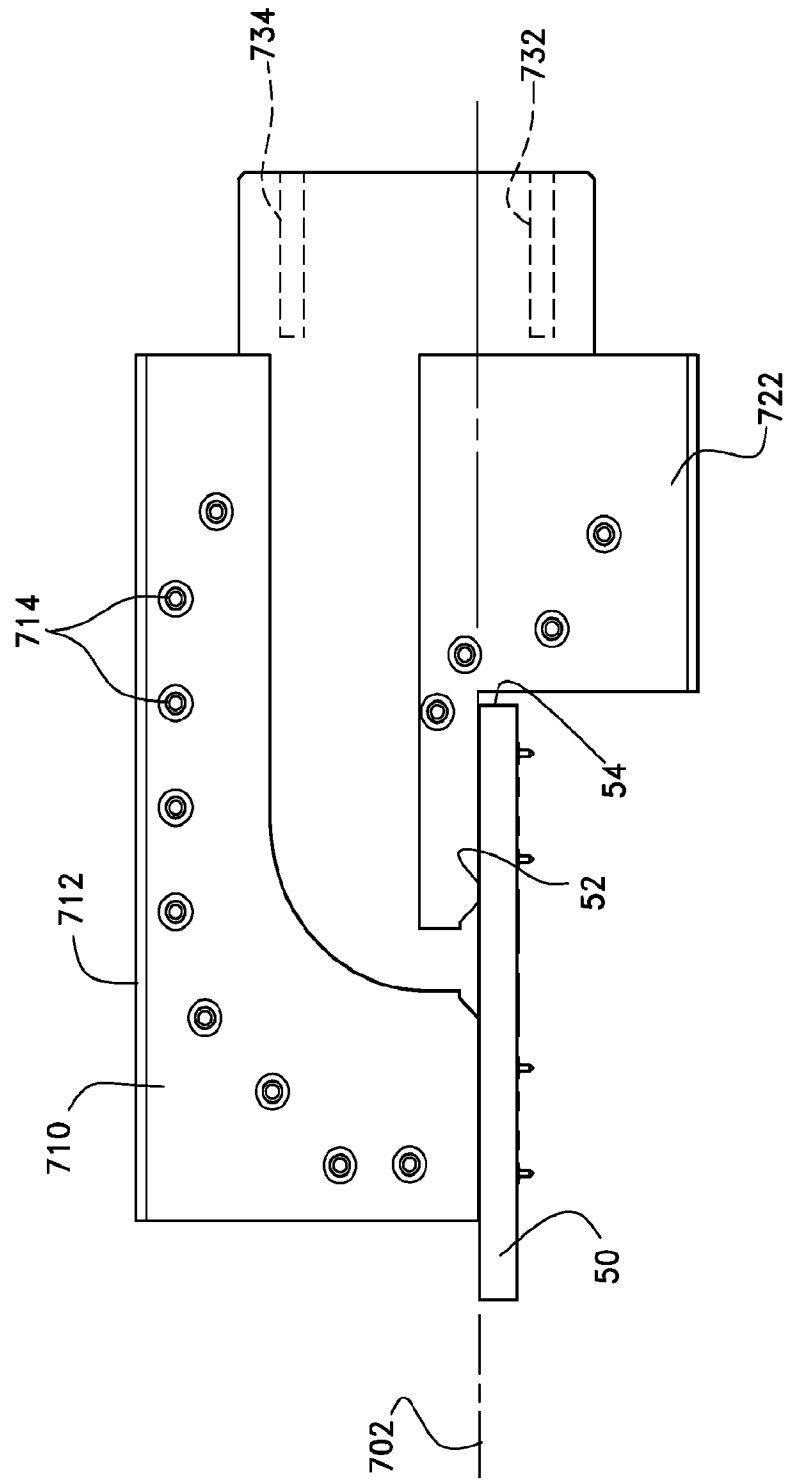


FIG. 24

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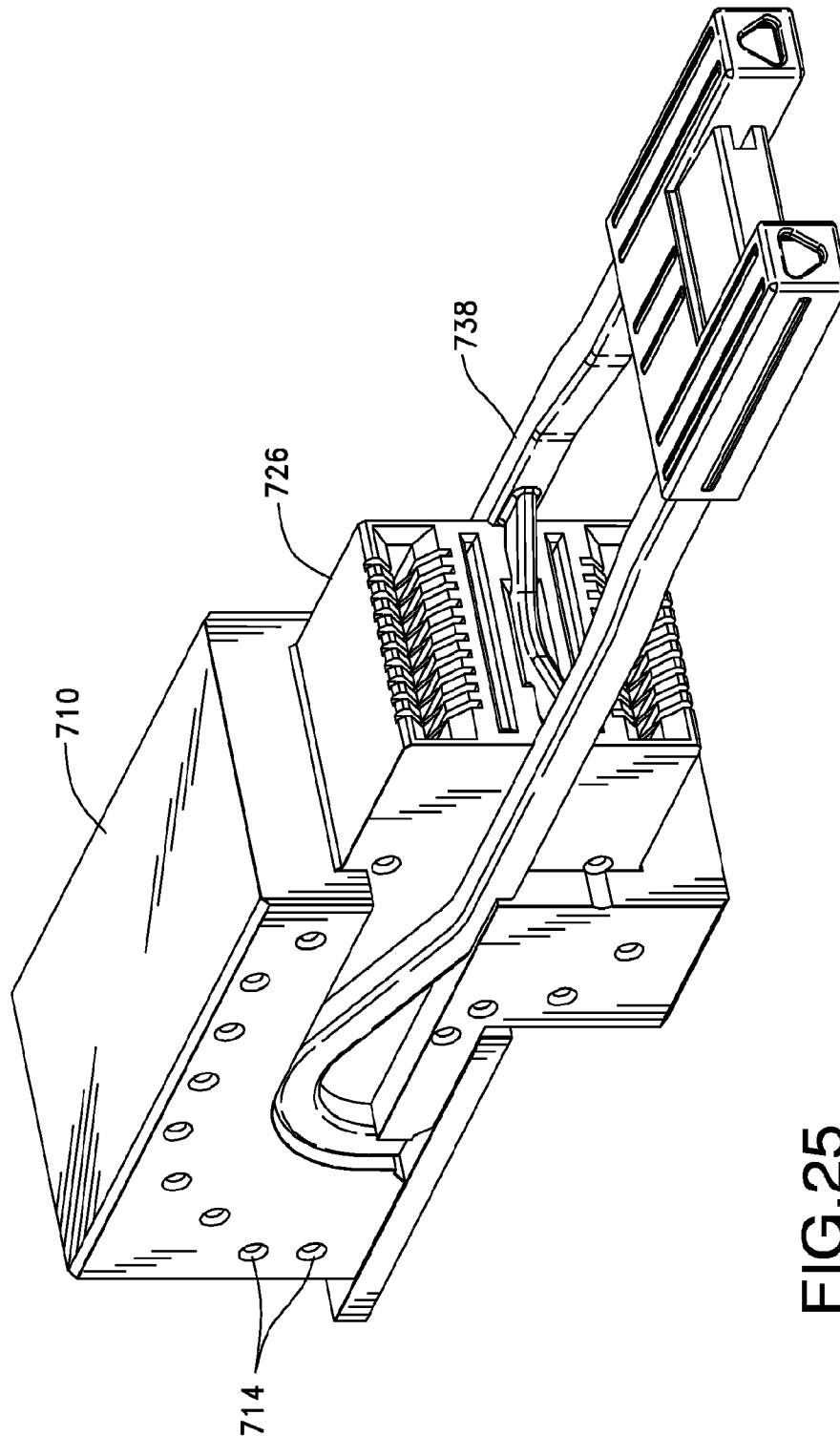
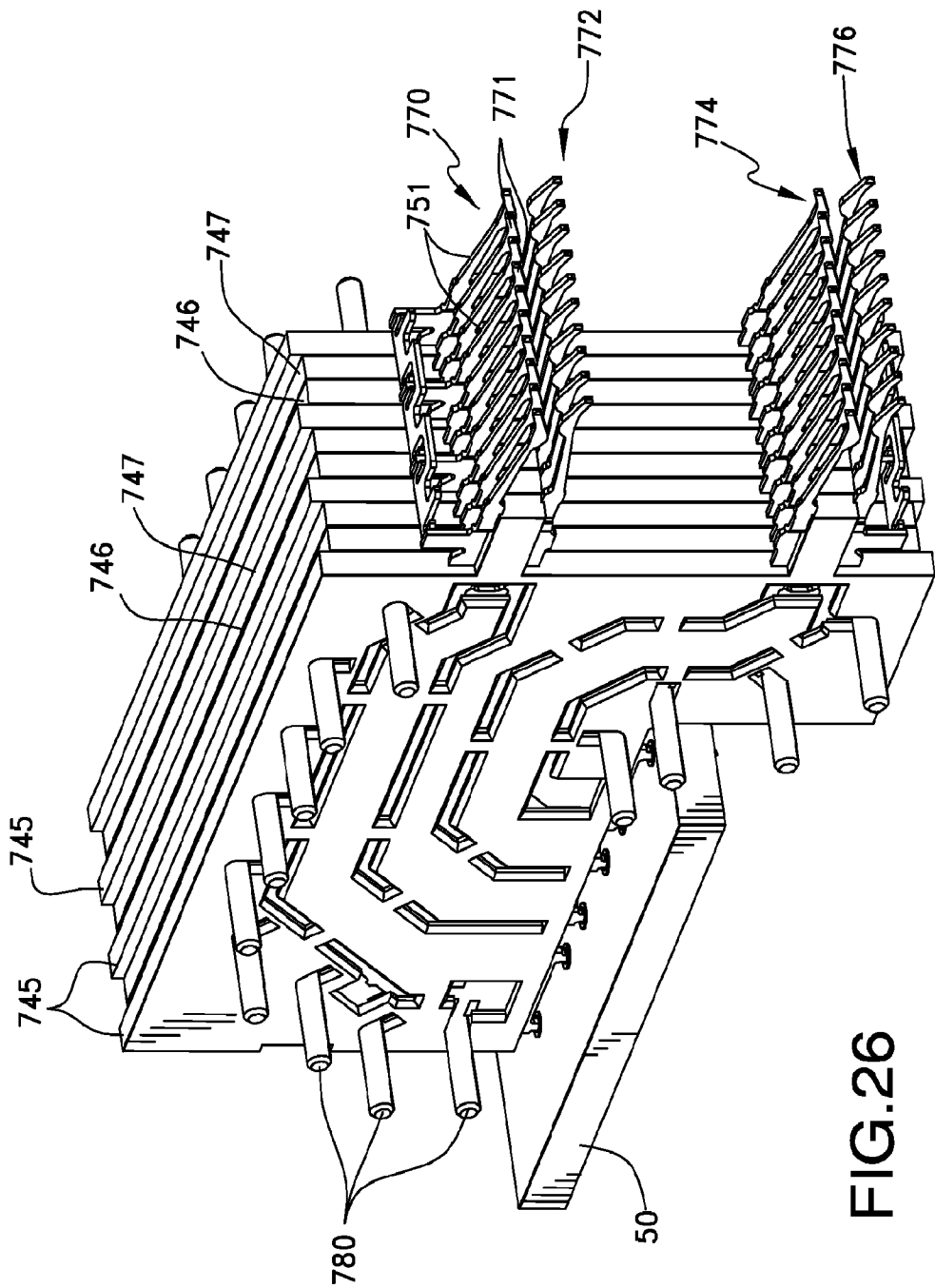
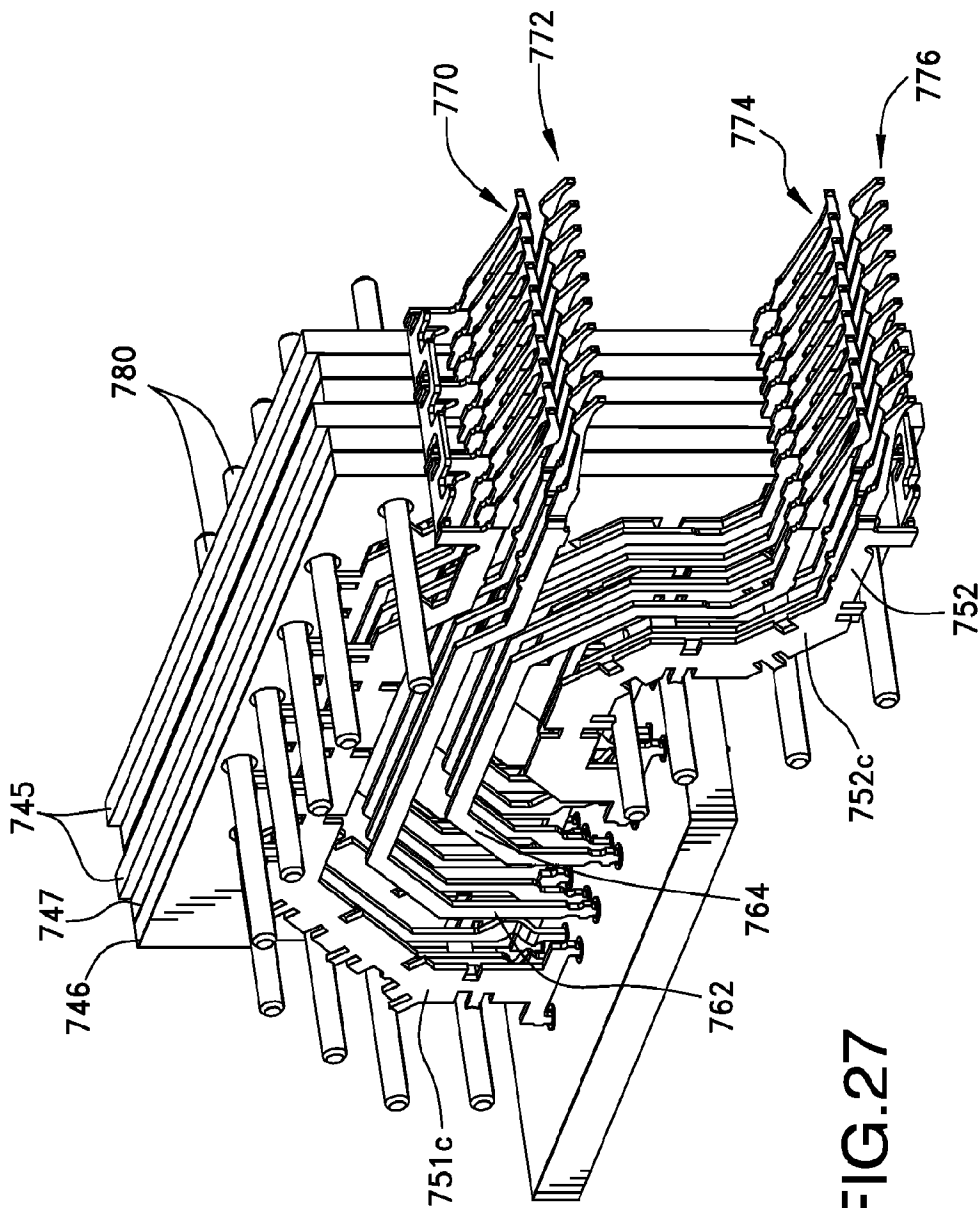
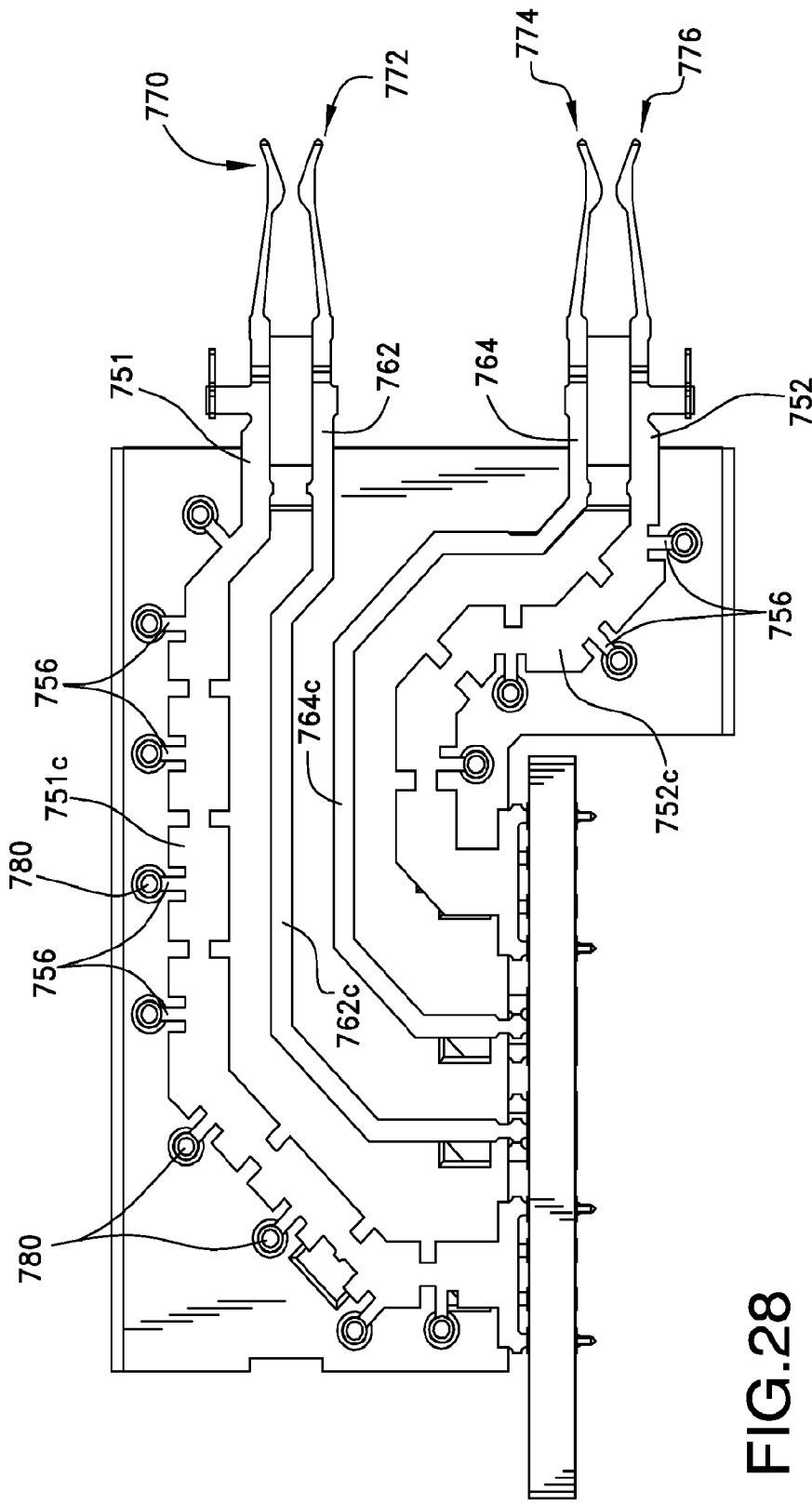


FIG. 25









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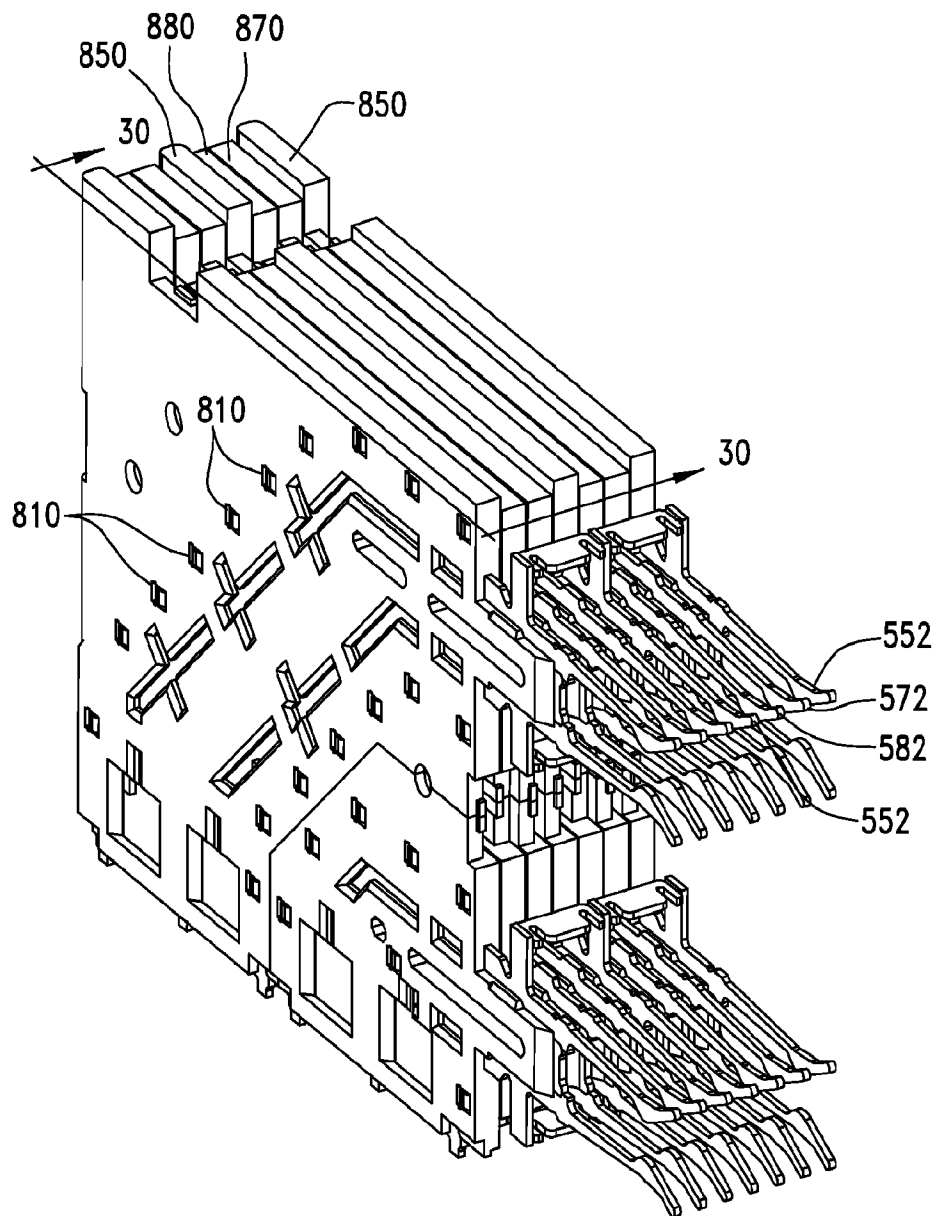


FIG.29

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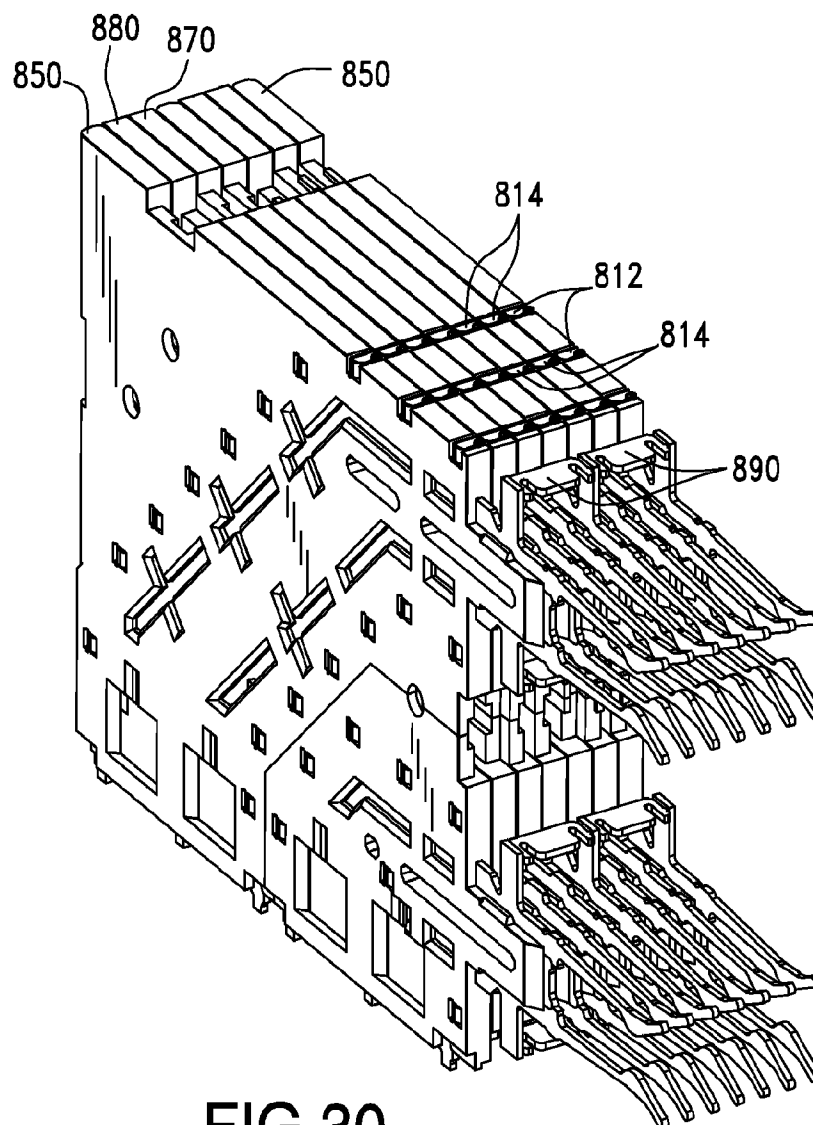
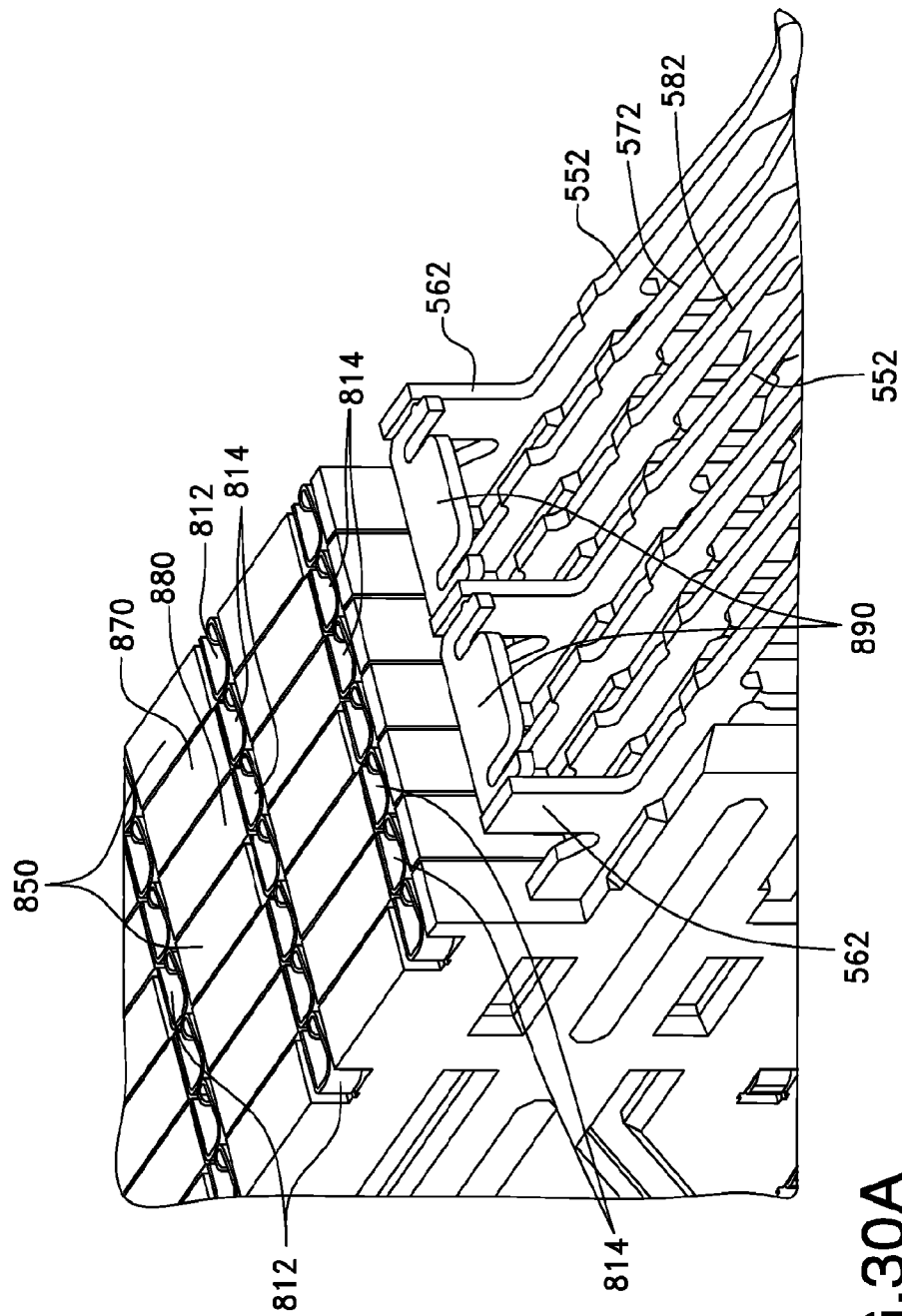


FIG.30



**FIG. 30A**

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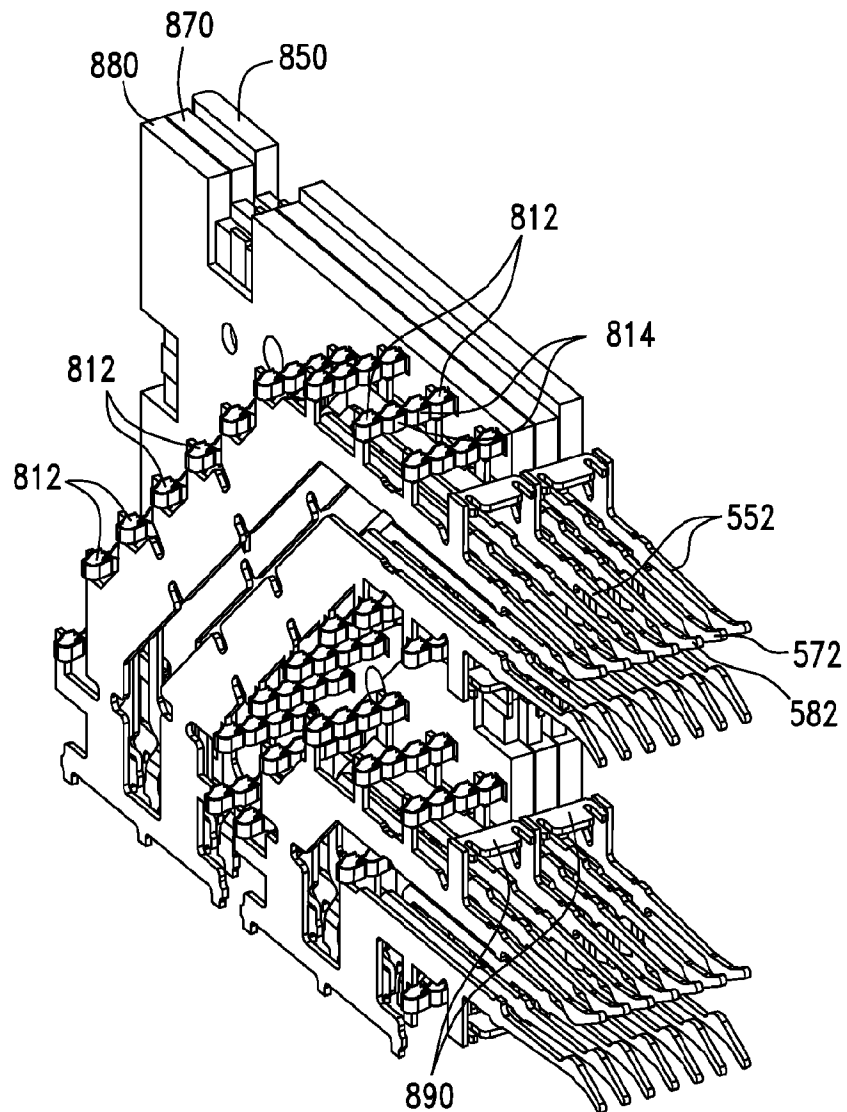
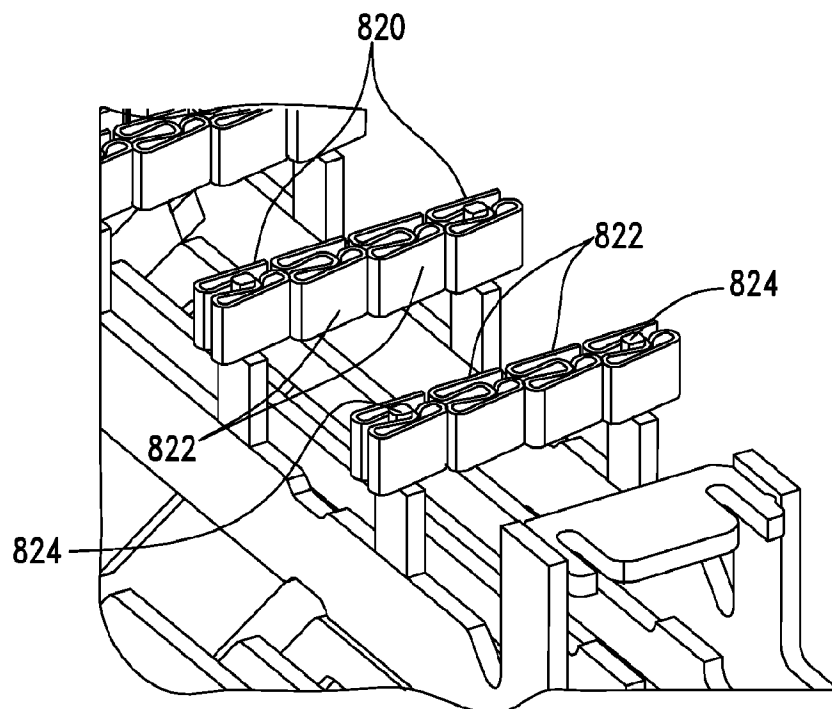
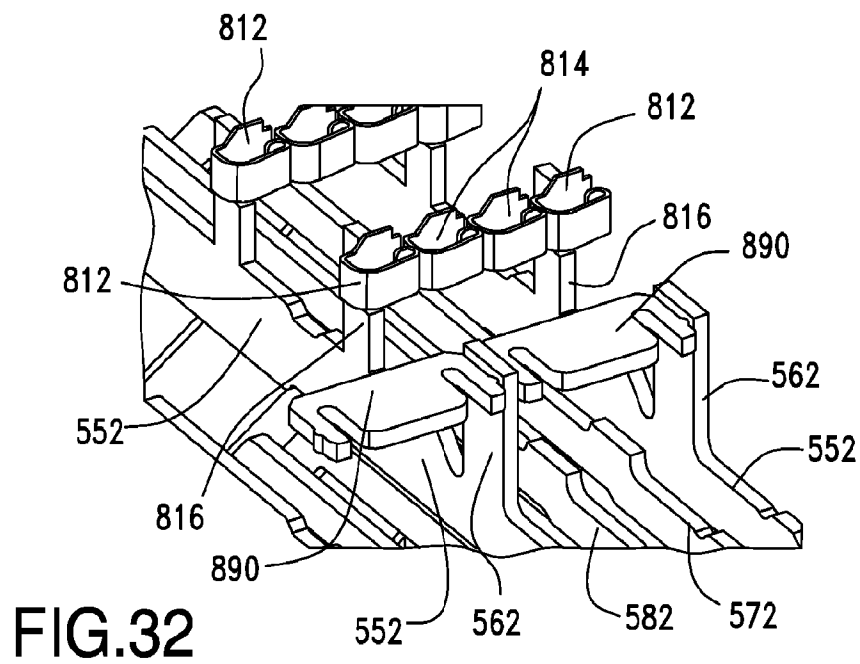


FIG.31

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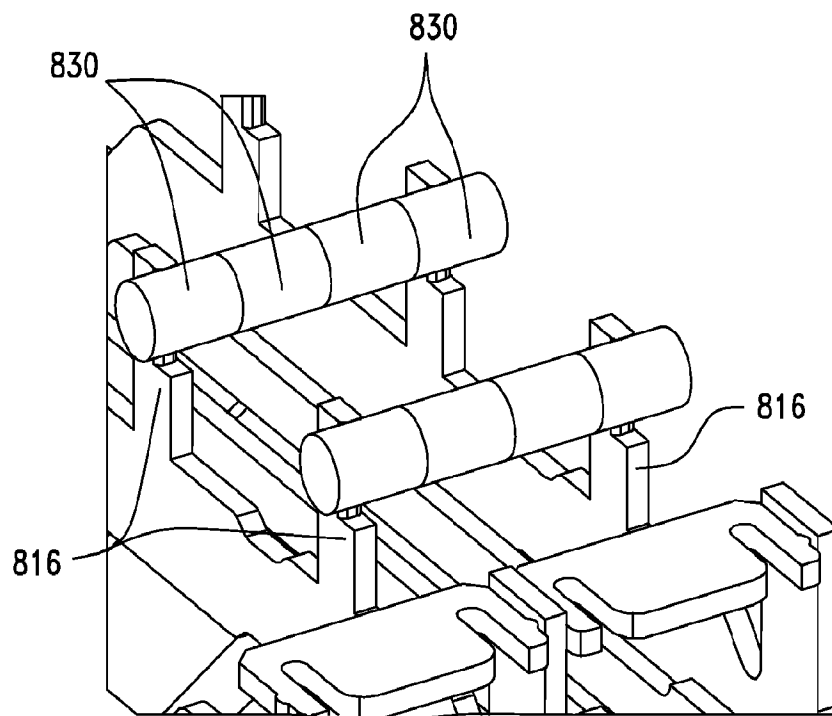


FIG.34

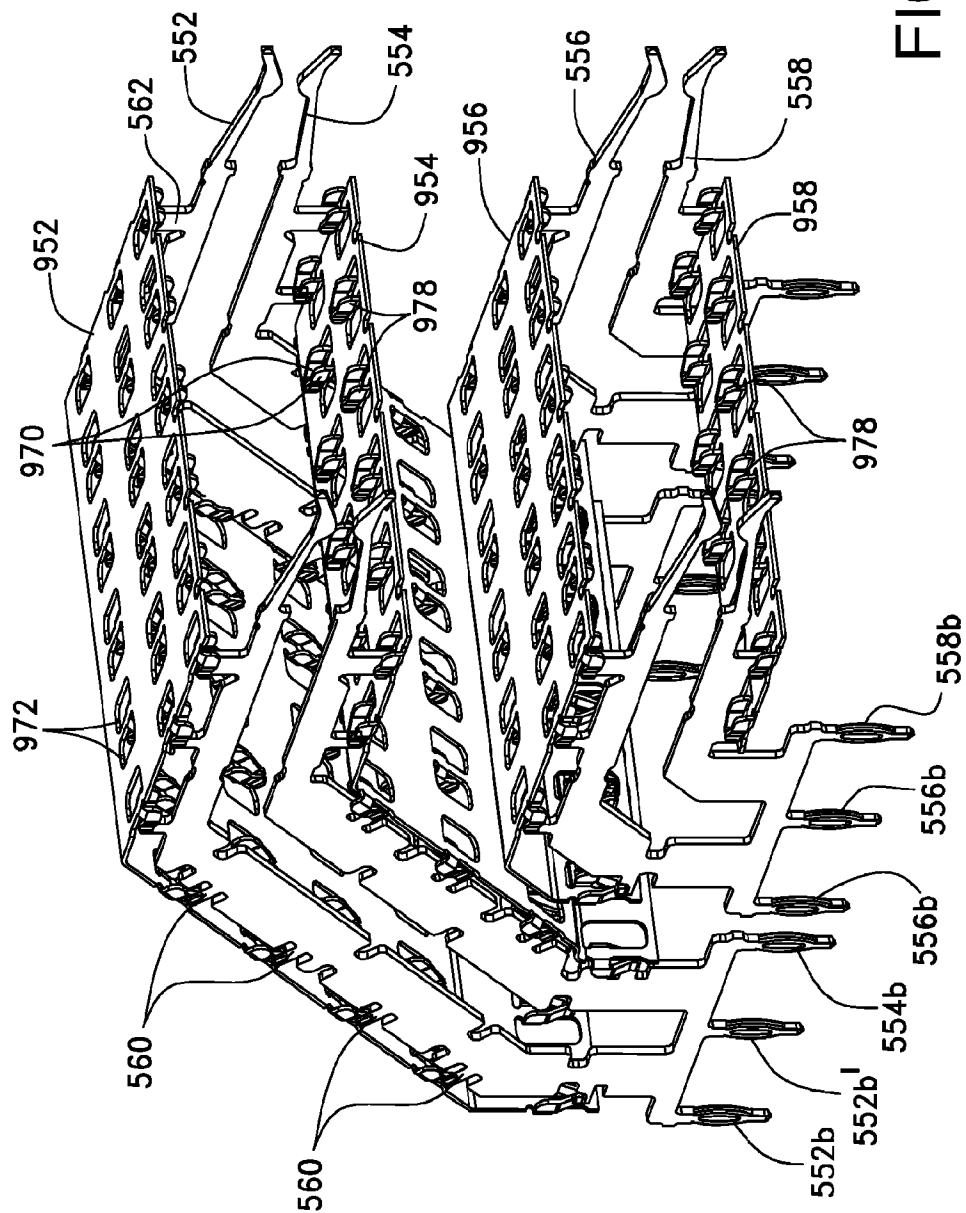
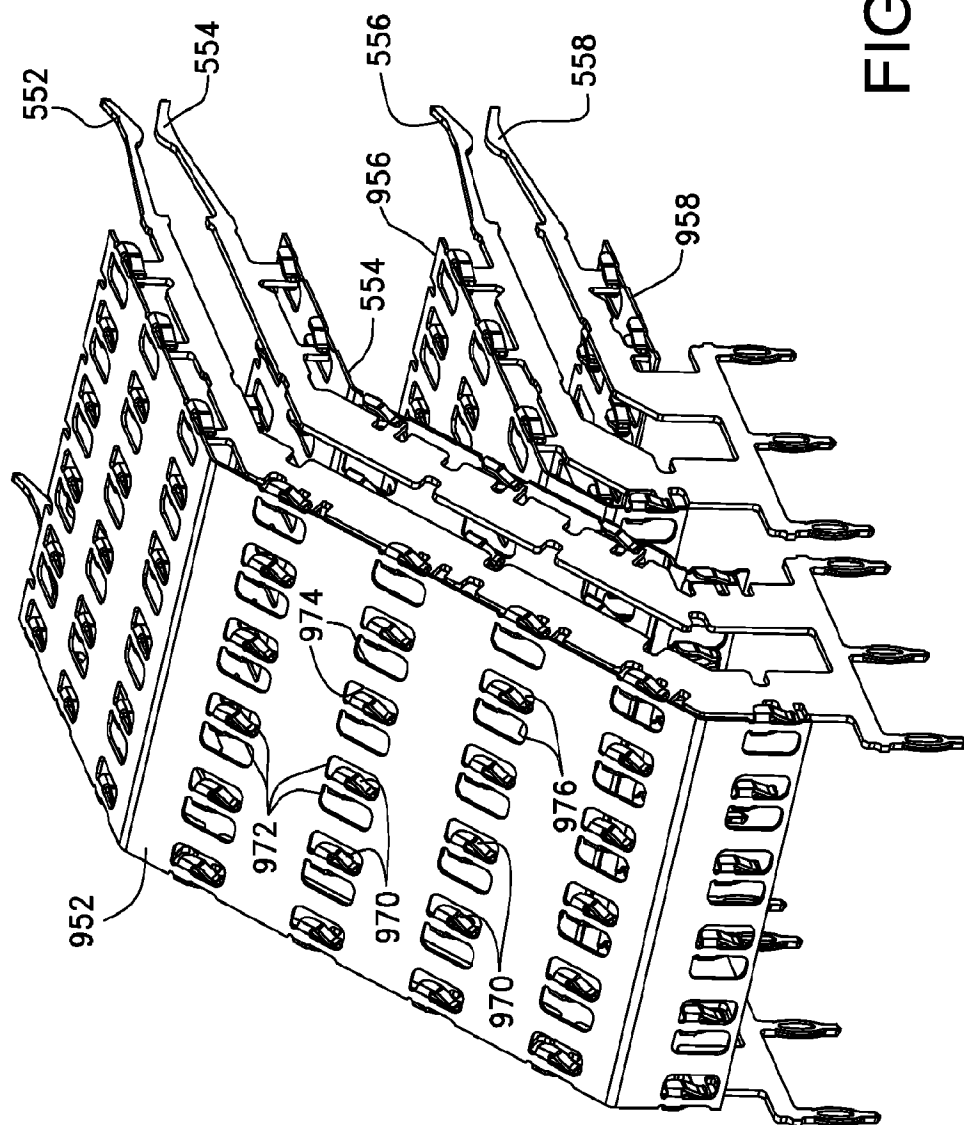


FIG. 35

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FIG.36





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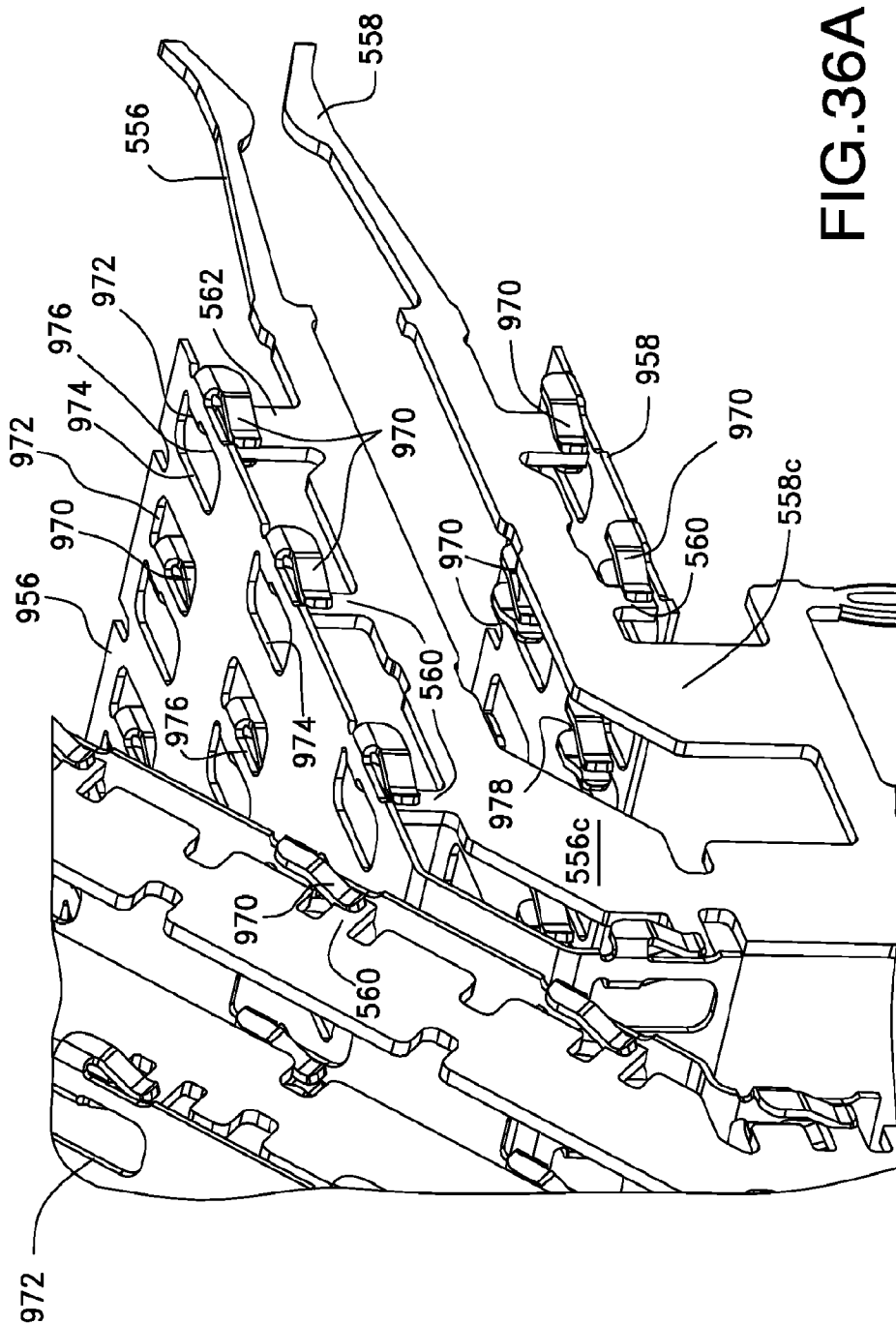


FIG. 36A

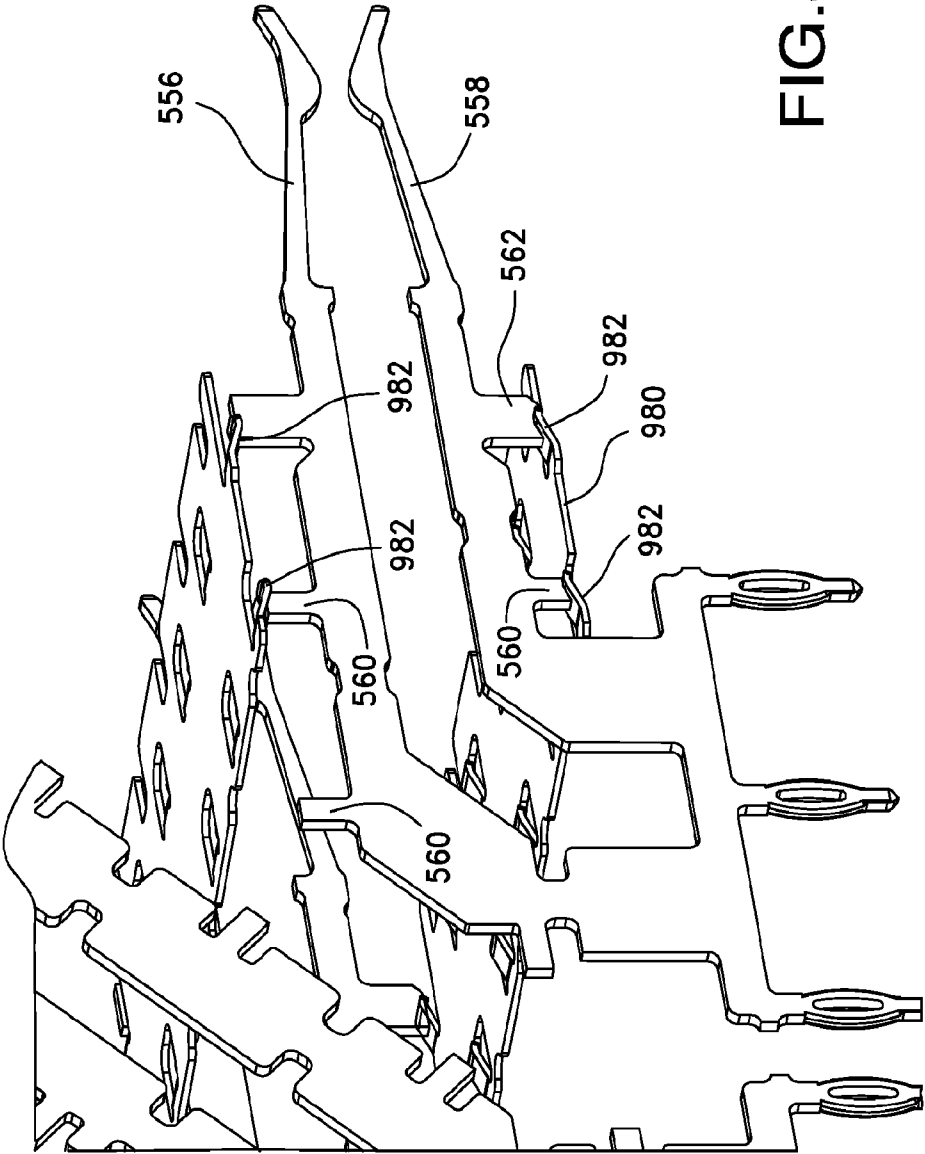


FIG.37

# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/067333

## A. CLASSIFICATION OF SUBJECT MATTER

INV. H01R12/14 H01R29/00  
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)

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, WPI Data

## 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 2003/181077 A1 (ROTHERMEL BRENT RYAN [US] ET AL) 25 September 2003 (2003-09-25) the whole document	1-8, 27-29 10,11, 17-26
X	US 6 220 896 B1 (BERTONCINI DANIEL B [US] ET AL) 24 April 2001 (2001-04-24) column 2, lines 44-54 column 3, lines 25-46 figures 3-7	9,12-14
Y	US 2006/189212 A1 (AVERY HAZELTON P [US] ET AL) 24 August 2006 (2006-08-24) the whole document	10,11, 17-20, 22-26

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

☒ See patent family annex.

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Date of the actual completion of the international search

27 April 2010

Date of mailing of the international search report

06/05/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2  
NL - 2280 HV Rijswijk  
Tel. (+31-70) 340-2040,  
Fax: (+31-70) 340-3016

Authorized officer

Ledoux, Serge

# INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/067333

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X,P	WO 2009/111283 A2 (FRAMATOME CONNECTORS INT [FR]; FCI AMERICAS TECHNOLOGY INC [US]; BUCK) 11 September 2009 (2009-09-11) the whole document -----	1,4-16, 22,23, 27,29

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Information on patent family members

International application No

PCT/US2009/067333

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