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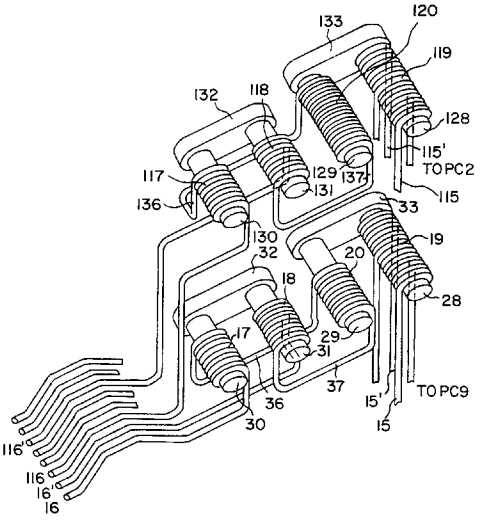
(54) **COMBINAISON DE FILTRE DE MODE COMMUN ET DE FILTRE/CONNECTEUR**

(54) **COMMON MODE FILTER AND FILTER/CONNECTOR COMBINATION**



(57) Un connecteur électrique comprend un filtre de mode commun avec une partie de bobine d'arrêt et une partie d'isolation électrique constituée de deux éléments formant âmes, comportant chacun deux branches d'âmes (28, 29, 30, 31). Un premier enroulement (19) est enroulé autour de la première branche (28) du premier élément formant âme pour former une première bobine de la section d'isolation. La bobine secondaire (20) de la section d'isolation et les deux bobines (17, 18 et 20) de la section de la bobine d'arrêt sont constituées par un enroulement unique qui peut être un seul fil métallique ou peut comprendre une partie connectée par une plaquette de circuits imprimés. Les extrémités du deuxième enroulement (16, 16') sont formées pour constituer les sections correspondantes de deux contacts RJ, tandis que les extrémités du premier enroulement (15, 15') sont formées pour constituer les broches en vue de l'insertion dans les ouvertures ménagées dans une carte d'interface de réseau de zone locale.

(57) An electrical connector includes a common mode filter with a choke portion and an electrical isolation portion made up of two core members, each core member having two core legs (28, 29, 30, 31). A first winding (19) is wrapped around the first leg (28) of the first core member to form a first coil of the isolation section, but the secondary coil (20) of the isolation section and both coils (17, 18 and 20) of the choke section are formed by a single winding which may be a single wire or may include a portion connected through a circuit board. The ends of the second winding (16, 16') are shaped so as to form the mating sections of a pair of RJ contacts, while the ends of the first winding (15, 15') are shaped to form pins for insertion into openings in a LAN interface card.

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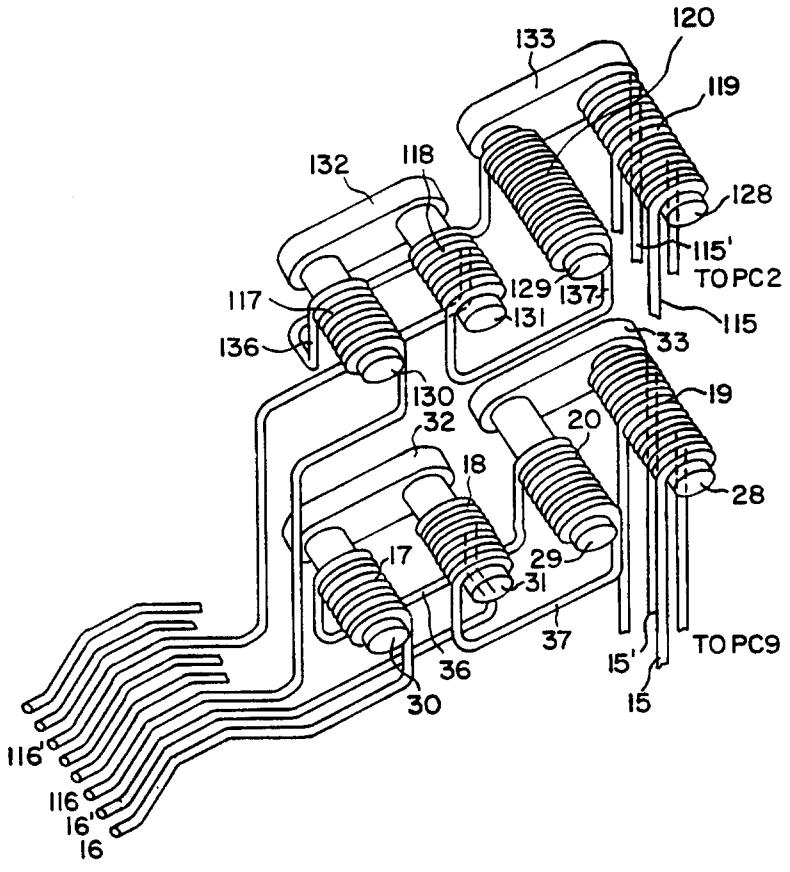
(54) Title: COMMON MODE FILTER AND FILTER/CONNECTOR COMBINATION

(57) Abstract

An electrical connector includes a common mode filter with a choke portion and an electrical isolation portion made up of two core members, each core member having two core legs (28, 29, 30, 31). A first winding (19) is wrapped around the first leg (28) of the first core member to form a first coil of the isolation section, but the secondary coil (20) of the isolation section and both coils (17, 18 and 20) of the choke section are formed by a single winding which may be a single wire or may include a portion connected through a circuit board. The ends of the second winding (16, 16') are shaped so as to form the mating sections of a pair of RJ contacts, while the ends of the first winding (15, 15') are shaped to form pins for insertion into openings in a LAN interface card.



*(Referred to in PCT Gazette No. 11/1998, Section II) **(Referred to in PCT Gazette No. 26/1998, Section II)

COMMON MODE FILTER AND FILTER/CONNECTOR COMBINATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the combination of an isolation circuit and a common mode filter circuit which may be used, by way of example, to connect a computer to a local area network (LAN), and to an electrical connector which includes such a combined isolation and common mode filter circuit.

The invention also relates to an electrical connector, and in particular to a circuit board mounted electrical connector which includes a main housing, a secondary housing containing transformer and/or filter components, means for securing the main housing to the secondary housing, and terminal structures for connecting the

windings of the transformer and/or filter components to the connector mating contacts and to said circuit board.

2. Description of Related Art

Electrical connectors known as modular phone receptacles or jacks have been known for many years. Although connectors of this type were originally designed for use in telephone systems, they have found wide acceptance in a variety of other contexts. For example, modular jacks are now commonly used as input/output (I/O) interface connectors for enabling computers to communicate with each other and with a variety of peripheral equipment, and in particular as connectors between a local area network (LAN) and an appropriately configured interface card.

In order to receive a corresponding modular plug, the conventional modular jack is generally made up of a socket housing which includes a plug-receiving opening, opposed top and bottom surfaces joined by opposed side surfaces extending from the opening to a back surface, and a plurality of stamped, metallic elongated contacts mounted in the housing for engaging contacts of the corresponding plug. Each contact in this type of connector includes a contact mating portion at one end extending diagonally into the socket, a vertically extending lead portion at the other end, and a horizontally extending intermediate portion between the contact mating portion and the lead

portion. Generally, the lead portions of the contacts are inserted directly into openings in the interface card and soldered in place.

Because the above-described type of modular jack is often used for digital communications, the devices in which this type of connector is used have a tendency to emit high frequency radiation which can interfere with other electrical equipment. In addition, the devices are themselves vulnerable to noise or transients induced in an incoming line by external sources. While adding filtering circuitry to the interface card can often be used to solve such problems, the difficulty of designing circuitry which meets current emissions requirements as well as space considerations suggests that inclusion of filtering or transient suppression capabilities in the connector would be desirable under certain circumstances, and in particular where the cost of providing on-board filtering exceeds the cost of adding filters to the connector.

In general, prior attempts to add common mode filtering to interface connectors for LANs and similar applications have fallen into one of three categories:

1.) connectors in which the filter components are provided on a miniature circuit board fitted into or onto the connector, as described in U.S. Patent No. 5,069,641 (Sakamoto *et al.*), or on circuit board traces applied

directly to the connector, as described in U.S. Patent No. 5,282,759 (Sakamoto *et al.*);

2.) connectors in which the connector contacts are inserted through central openings in a ferrite block which forms the inductive component of the common mode filter, as described in U.S. Patent Nos. 4,772,224 (Briones) and 5,397,250 (Talend); and

3.) connectors in which the contacts are wrapped around the filter components, as described in U.S. Patent Nos. 5,015,204 (Sakamoto *et al.*) and 5,139,442 (Sakamoto *et al.*).

Filters of the first type, in which the circuitry is provided on a printed circuit board, have the disadvantage that they are relative expensive in comparison with corresponding circuitry mounted on a host interface card or circuit board, due to the limited space available within the standard connector and the consequent need for miniaturization. Filters of the second and third types, on the other hand, are simpler to install and use less expensive bulk components, but have the disadvantage of failing to offer electrical isolation between input and output circuits, as a result of which the isolation circuitry must still be provided on the host circuit card.

Figures 1A-1C show a typical example of the third type of prior art filtering arrangement mentioned above, in which the common mode filter is formed by wrapping the

connector contacts around a ferrite core, as disclosed in U.S. Patent No. 5,015,204. The prior arrangement provides an inductive core 1, which is positioned at the rear of an RJ connector, and contacts that extend from a first end, the first end being in the form of a front mating interface portion 2 arranged to engage corresponding portions of the contacts of an RJ connector plug, to a second end which forms PCB tails 3 for insertion into openings in a printed circuit board 6. In order to form the common mode filter, the electrical schematic for which is illustrated in Figure 1A, the contacts are wrapped around legs 4 of the inductive coil 1 to form coils 5.

In order to accommodate the filter, the conventional arrangement requires modification of the connector by constructing the connector of a lid member 8 and a base member 7 having an extension 9 which separates the interior of the connector into a plug receiving chamber 10 and a filter accommodating chamber 11. The filter is positioned in the chamber 11 by a cavity 12 provided in the base member 7, and held in place by a pressure bar spring 13 itself positioned in a positioning member 14 depending from the lid member 8 or upper half of the connector housing.

As indicated above, the disadvantage of this arrangement is that it cannot accommodate both the common mode filter and isolation circuitry, and thus it has conventionally been necessary to include a transformer on

the interface card, or eliminate bulk components in favor of circuit traces at the rear of the connector and a prepackaged miniature transformer of the type described, for example, in U.S. Patent No. 5,403,207.

As will be discussed in more detail below, one aspect of the present invention is to modify the concept exemplified by the arrangement illustrated in Figures 1A-1C by providing a first embodiment which includes within the connector both a common mode filter and an isolating transformer, while using easily assembled bulk components. This is basically accomplished by separating the front portion of the RJ contact structure from the portion which extends from the connector and is inserted into the host circuit board or interface card, and by utilizing a unique core and winding structure that enables assembly of the filter and transformer structures in an especially efficient manner so that all of the circuitry shown in Figure 2 can be placed within a connector rather than on the circuit board. In this first embodiment, the mating contacts are formed by extending the inductor windings to form the contacts, and the PCB tails are in the form of extensions of the transformer windings.

An alternative approach is provided by the second through seventh embodiments of the invention, in which the integral mating contact and PCB tail structures of the first embodiment of the invention are replaced by separate

mating contact and PCB tail structures. Instead of forming contact tails from the windings, the contact tails are incorporated into the base of the housing structure, and the ends of the windings on the transformer and inductor cores are connected to fixed terminals extending from the base of the housing and connected respectively to the contact tails and the connector contacts. This alternative simplifies assembly of the connector while maintaining the advantages of the first embodiment by allowing the filter and transformer components to be pre-wound and connected to the base before assembly of the base to the connector, and increases design flexibility because the terminal pattern and interconnections between the terminals can easily be varied without varying the housing footprint or the component mounting arrangement.

SUMMARY OF THE INVENTION

It is accordingly a first objective of the invention to overcome the disadvantages of prior common mode filters by providing a common mode filter which is simple in structure and easily assembled to an electrical connector.

It is a second objective of the invention to provide an electrical connector having a common mode filter which is simple in structure, provides electrical isolation, and easily assembled.

It is a third objective of the invention to provide an RJ connector having a common mode filter which is simple in structure, provides electrical isolation, and in which the filter is easily assembled to the connector.

It is a fourth objective of the invention to provide an improved circuit board mounted connector which permits use of pre-wound one-piece transformer and/or inductor core structures, and which is easily adaptable to a variety of housing and circuit configurations.

The first three objectives of the invention are achieved, in accordance with a first preferred embodiment of the invention, by providing a common mode filter in the form of a pair of pi-shaped core members made of a material having magnetic properties which are assembled together to form, together with cap or cover members, the core of an inductor, and in which the inductor windings are formed not by wrapping individual contacts around respective legs of the core, but rather are partially formed by wrapping the connector contacts around the legs of one of the cores to form the common mode filter and by then wrapping the contacts around one of the legs of the second core to form a first winding of an isolation transformer, the second winding of the isolation transformer being provided by a discrete contact member which forms the connector's printed circuit board tails, or by wrapping the connector contacts around both legs of one of the connector cores to form the

common mode filter, and connecting the common mode filter with a discrete winding of the isolation transformer via the circuit board, the other winding of the isolation transformer being provided by a discrete contact member which forms the connector's printed circuit board tails.

Alternatively, the objectives of the invention are achieved, in accordance with second through seventh embodiments of the invention, by providing a circuit board mounted electrical connector which includes a main housing, a secondary housing containing transformer and/or filter components, means for securing the main housing to the secondary housing, and separate terminal structures for connecting the windings of the transformer and/or filter components to the connector mating contacts, to the PCB tails, and to each other. The mating contacts and the terminal structures of these embodiments of the invention may be mounted together on a base module, on an extension of the secondary housing, or separately on the base and on an extension of the secondary housing, while the electrical components can be mounted in the secondary housing in a variety of orientations.

The transformer and inductor arrangements of these embodiments are particularly advantageous relative to an arrangement of the type described in U.S. Patent No. 5,015,204, because the filter of the invention provides isolation between the plug and board-side contacts, whereas

the arrangement of the previous connector provided a continuous path around the inductor with no isolation. While prior common mode filters existed which provided isolation, such as the one in 5,282,759, the isolation was achieved at the cost of greatly increased complexity.

In addition, in each of the preferred embodiments of the invention, the connector may be in the form of an RJ connector, for example a high speed RJ-45 connector of the type typically used on network or communications interface cards, although the principles of the invention could possibly be used in a variety of applications requiring a simplified circuit board mounted connector structure in which the connector includes isolating and filtering components.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A is a schematic circuit diagram showing a conventional common mode filter.

Figure 1B is a perspective view of a conventional implementation of the common mode filter of Figure 1A.

Figure 1C is cross-sectional side view of an RJ-type connector plug including the conventional common mode filter illustrated in Figure 1B.

Figure 2 is a schematic circuit diagram of a common mode filter and isolation transformer arrangement constructed in accordance with the principles of a preferred embodiment of the invention.

Figure 3 is a perspective view of an implementation of the common mode filter and isolation transformer arrangement schematically illustrated in Figure 2, but with no center tap on the primary side of the transformer.

Figure 4 is a cross-sectional side view of a connector which incorporates the common mode filter implementation illustrated in Figure 3, and includes a center tap on the primary side of the transformer.

Figure 5 is a cross-sectional side view of a variation of the common mode filter implementation illustrated in Figure 4.

Figure 6 is a perspective view of transformer and inductor structures suitable for use in connection with the preferred embodiments of the invention.

Figure 7 is an exploded perspective view showing the various housing parts of a connector constructed in accordance with the principles of a second preferred embodiment of the invention.

Figure 8 is a perspective view of LED lead extensions which may be incorporated into the preferred embodiments of the invention.

Figure 9A is a cross-sectional side view taken along line B-B in Figure 9C.

Figure 9B is a cross-sectional side view taken along line A-A in Figure 9C.

Figures 9C-9G are respective top, side, bottom, front, and rear views of the terminal supporting base illustrated in Figure 7.

Figure 10 is a front view of the assembled connector of the third preferred embodiment of the invention.

Figure 11 is a side view of the assembled connector of a fourth preferred embodiment of the invention.

Figure 12A is a partially cross-sectional side view of a main housing constructed in accordance with the principles of the third preferred embodiment of the invention.

Figure 12B is a rear view of the main housing shown in Fig. 12A, with contacts removed.

Figure 13 is a cross-sectional side view of an assembled connector constructed in accordance with the principles of the third preferred embodiment of the invention.

Figures 14A-14C are respective side, top, and front views of a secondary housing for the connector of the third preferred embodiment of the invention.

Figure 15 is a rear view of a main housing constructed in accordance with the principles of a fourth preferred embodiment of the invention.

Figure 16 is a cross-sectional side view of an assembled connector constructed in accordance with the principles of the fourth preferred embodiment of the invention.

Figures 17A-17B are respective side and top views of a secondary housing for the fourth preferred embodiment of the invention.

Figures 18A and 18B are respective side and top views of secondary housing constructed in accordance with the principles of a fifth preferred embodiment of the invention.

Figures 19A and 19B are respective side and top views of the secondary housing constructed in accordance with the principles of a sixth preferred embodiment of the invention.

Figures 20A and 20B are respective side and top views of a portion of a base assembly constructed in accordance with the principles of a seventh preferred embodiment of the invention.

Figure 21 is a side view of a main housing for the connector of the seventh preferred embodiment.

Figure 22 is a side view of a secondary housing for the connector of the sixth preferred embodiment.

Figure 23 is a side view of the assembled connector of the seventh preferred embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

In the schematic circuit diagram of Figure 2, the terminals indicated by reference numerals 16 and 16' correspond to the mating ends of the conventional RJ contacts 2 illustrated in Figure 1C, and the terminals indicated by reference numerals 15 and 15' correspond to the downwardly extending portions 3 of the conventional RJ contacts illustrated in Figure 1C. It will be appreciated

by those skilled in the art, however, that the principles of the invention may be applied to contacts other than "RJ" contacts, *e.g.*, contacts in which the mating portion has a configuration other than the acute angle of the RJ contacts illustrated in Figure 1C, or contacts in which the downwardly extending portions are arranged for surface mounting or for plugging into openings in the circuit board rather than for insertion therein and subsequent soldering in place.

The circuit illustrated in Figure 2 includes both inductor or choke coils 17,18 and also isolation coils 19,20. Because isolation coils 19 and 20 are not physically connected to each other, the "wires" on either side of the isolation or transformer coils are discrete structures, and instead of connecting terminals 15 and 15' to respective terminals 16 and 16' as in the prior art, terminals 15 and 15' are connected to each other and terminals 16 and 16' are connected to each other, such that coil 19 and terminals 15 and 15' form a single contact structure and coils 17, 18, and 20 together with terminals 16 form a second contact structure. Terminal 23 illustrated in Figure 2 is an optional center tap for the primary winding of the isolation transformer, while terminal 24 is an optional center tap for the secondary winding of the isolation transformer.

Although terminals 16 and 16' are described as corresponding to the contacts of an RJ connector, and terminals 15 and 15' are described as PCB tails, with the common mode filter being located between the connector contacts and the transformer, those skilled in the art will note that the filter could also be located between the isolation transformer and the terminals connected to the circuit board, and that the invention in its broadest form should not be limited to any particular terminal structure for either terminals 15 and 15' or terminals 16 and 16'.

The core structures for the combined common mode filter and isolation transformer of the first preferred embodiment of the invention, as best illustrated in Figure 3, include two closed cores 26 and 27, each made up of two legs 28-31 and two end caps (of which only the first end cap 32,33 of each core is shown). The core legs and end caps are each made up of a magnetic material such as a ferrite material with high magnetic permeability and high electrical resistivity, although the material of the different cores may have different magnetic properties based on their different functions. It will be appreciated by those skilled in the art that the separation of the cores 26 and 27 into legs 28-31 and caps 32-35 is for convenience in manufacturing the cores and wrapping the respective contacts around them, rather for any electrical purpose, and that the core structure may be varied from the cylindrical leg/flat end cap structure shown (for example,

it may be convenient to form the legs and one of the end caps as a unit, and then to add the second end cap after winding).

In this implementation of the preferred common mode filter, coil 19 is wrapped around core leg 28 to form the first winding of the isolation section of the preferred circuit. The two ends of coil 19 extend downwardly from the coil and are shaped into PCB tails or terminals 15 and 15' for engaging conductive elements on a circuit board (not shown). It will be appreciated, as indicated above, that sections 15 and 15' may have different shapes depending on the requirements of the board or card with which the connector is to be used, and that these terminals may also be shaped to accommodate, for example, insulation displacement contacts or various other contact configurations for connection to a flat cable or other device.

Coils 17, 18, and 20, are preferably formed in this embodiment by a single wire starting at one of the terminals 16, and which is first wrapped around core leg 30 and then wrapped, via a connecting section 36, around core leg 29, via a connecting section 37 around core leg 31, and finally extends to terminal 16' to thereby form the network side of the connector wiring. It will again be appreciated that terminals 16 and 16' may have shapes other than the

illustrated RJ contact shapes depending on the device to which these sections are to be connected or terminated.

In addition to the first filter and transformer structures described above, the arrangement illustrated in Figure 3 includes a second filter and a second isolation transformer arranged above the first filter and isolation transformer. The winding arrangement for the second filter and isolation transformer is the same as for the first filter and isolation transformer, and thus will not be described in detail herein except to note that reference numerals 15-37 for the first set of components correspond respective to reference numerals 115-137 for the second set of components.

As illustrated in Figure 4, the common mode filter arrangement of this embodiment of the invention may be used in an RJ type connector as follows, although those skilled in the art will appreciate that the illustrated connector is not the only connector to which the principles of the invention may be applied. As is conventional, the connector of this embodiment includes a molded plastic housing 38 which includes a cover or lid member 40 which forms the top 41, rear 42, and sides (not shown) of the connector, and which includes a downwardly depending wall 43 for dividing the interior of the connector into a front chamber 44 for receiving the mating plug connector and a rear chamber 45 for accommodating the contact. Dividing

wall 43 includes grooves, or simply ends a small distance from the bottom side of the connector, to permit passage of a portion 47 of the mating sections 16, 16', and optionally, primary winding center tap 23.

Also shown in Figure 4 is an optional second common mode filter and isolation transformer arrangement isolated from the first common mode filter and isolation transformer by isolating partition or partitions 49 and corresponding to the second filter and transformer arrangement illustrated in Figure 3. The structure of the second filter/transformer arrangement is identical to that of the first arrangement, except that the terminating leads 115, 115', as well as optional leads 123 and 125 extend through openings in partition 49 and through the lower portion of rear chamber 45 to reach the circuit board. The parts of the second arrangement corresponding to parts 15-23, 25-28, 36, and 37, have been numbered respectively as elements 115-123, 125-128, 136, and 137.

Those skilled in the art will appreciate that the front-to-rear dimension of the rear chamber 45 may be larger than that of the corresponding chamber in the conventional connector illustrated in Figure 1C so as to accommodate two cores rather than a single core. In general, at least in interface cards, it is the width and height of the connector that is more limited than the depth, and thus there is some freedom to adjust the

dimensions of the connector as necessary. This adjustment is somewhat facilitated in that, in the illustrated connector, the mating contact sections extend from the bottom of the plug receiving chamber 44 rather than the top. In this configuration, the ends 50 of the contacts are positioned against a shoulder or overhang 51 at the front of the connector, with the contact bias obtained by bending the contacts as illustrated being in the upper direction. It will of course also be appreciated by the skilled artisan that the illustrated design could easily be adapted for use with contacts arranged to extend from the top rather than the bottom of the plug receiving chamber.

In the variation of the first preferred embodiment shown in Figure 5, ends 36,37 and 136,137 of the transformer windings are routed to the printed circuit board directly from the isolation transformers, and are connected via the circuit board to terminals 36',37' and 136',137' for the common mode filters. This variation has the advantage of simplifying the construction of the transformer circuitry by separating the front and rear sections so that some of the windings are reduced in length and therefore made easier to manufacture and assemble. In addition, by separating the network side transformer winding from the common mode filter windings, different size or type wires can be used for each winding.

Assembly of the connector of the first preferred embodiment of the invention simply involves winding the appropriate core legs, shaping the ends of the contacts as desired, positioning the core structures on a base of the connector such that the terminals extend through openings in the base, and attaching the lid member 40 to capture the filter structure and contacts. While additional core positioning structures may be added as a matter of design choice, for example by using recesses and fixing members in the manner of the illustrated conventional connector, it is noted that no electrical connections need be made when assembling the connector, as would be the case in the types of connector in which the electrical components are in the form of packages having leads which was be connected to the contacts.

In order to even further simplify assembly of the connector of the invention, the second through seventh embodiments of the invention dispense with the need for wiring of the cores in the manner described above, but instead use separate pre-wired transformer and choke cores, with interconnections between the cores being facilitated by the arrangement of the connector housing. The wiring for the filter and transformer structures of these embodiments may be identical or similar to those disclosed above in connection with the first preferred embodiment of the invention and illustrated in Figure 2, with the principal difference between the first preferred embodiment

and the second through seventh embodiments being that the filter and transformer structures are preferably in the form of pre-wired cores having windings which are connected to each other to obtain the desired filter and/or transformer circuits via terminals extending through the base of the connector, the terminals including PCB tails for interconnection via traces on the circuit board.

Examples of inductor and transformer cores which may be used in connection with the second through seventh preferred embodiments of the invention are schematically represented in Figure 6. The cores illustrated in Figure 6 include a pair of choke or inductor cores 120 and 121 having respective windings 122 and 123, and transformer cores 124 and 124' including primary windings 125 and 125' and secondary windings 126 and 126'. As illustrated, the choke cores have a horizontal orientation and the transformer cores have a horizontal orientation, although those skilled in the art will appreciate that the orientation and position of the cores may be varied as necessary to fit within the connector, and that the number and configuration of the cores and windings may be varied as necessary to meet the electrical requirements of the connector in which they are to be used, including the use of multiply tapped windings and non-toroidal core structures. While the cores are preferably each made up of a magnetic material such as a ferrite material, the

material of the different cores may have different magnetic properties based on their different functions.

The cores are connected to each other, to the connector contacts, and to circuitry on the circuit board on which the connector is situated by contacts 130 extending upwardly from the base 131 of the connector housing, the housing also including a main housing 132 and a secondary housing 133. Some of the contacts 130 extend through the base to form PCB tails 130' which connect with traces on the circuit board, while others directly connect windings on adjacent cores and are not terminated to the circuit board. In addition, the terminals may take a variety of forms, including the illustrated clamp contact structures as well as, for example, straight pins, with the terminal interconnections having been omitted from the illustrated connector in the interest of clarity.

While those skilled in the art will easily be able to provide proper traces and connections as required to form circuits such as the one illustrated in Figure 2, in the illustrated embodiment, two contacts a and b of the forward row of contacts 130, as shown in Figs. 9C-9E, include a PCB tail 130' for connection to traces on the circuit board to which the connector is mounted, while all of the contacts 130 in the second row include PCB tails 130'.

The main housing 132 of this embodiment includes a standard RJ connector opening 134 for receiving a mating plug connector, openings 135 and 136 for receiving LEDs 137 and 138, and notches 139 in the side walls of the main housing for receiving portions 139' of base 131, which forms the bottom wall of the main housing.

Base 131 includes a slotted front portion 140 for supporting RJ contacts 141, each of which includes an oblique section 142 for engaging a corresponding contact of the mating connector, a horizontal section 143 which passes through a passages 144 provided in the base, and either an upwardly extending vertical section 145 as illustrated in Figure 9B or a downwardly depending vertical section 146 as illustrated in Figure 9A. Vertical sections 145 extend upwardly from the base to serve as terminals for the windings of the choke coils, with slots 147 being provided to facilitate bending of the contacts to form the vertical sections 146, while vertical sections 146 extend downwardly and are directly terminated to the circuit board on which the connector is situated. As is known, bending of the front mating portions of the contacts may be facilitated by a lip 148 at the front of the passages.

While the illustrated connector uses standard RJ contacts, however, it will be appreciated by those skilled in the art that the form of the mating portions of the contacts is not essential to the invention, and may be

varied without departing from the scope of the invention. For example, it is possible that the contacts could take the form of cantilevered contacts extending horizontally from the rear of the plug opening.

Alignment between the base 131 and main housing 132 may be achieved by providing ribs 149 on the front section, and corresponding grooves 150 in the main housing. In addition, the base may be secured to the main housing by a wide variety of means, including but not limited to the illustrated tab and slot arrangement, in which tabs 151' are provided on the base and arranged to snap into openings (not shown) in the housing as ribs 149 are inserted into slots 150.

The base 131 is also aligned with the secondary housing 133 by a slot and groove arrangement including ribs 151 provided on a rear portion 152 of the base and slots 153 provided in the secondary housing for receiving ribs 150. While it is within the scope of the invention to provide a means for securing the base directly to the secondary housing, in the illustrated example, the secondary housing includes a forward extension 154 provided with resilient tab 155 for engaging corresponding opening 155' in the top wall of the main housing 132, and openings 155" for engaging tabs (not shown) thereby providing an example of a means for securing the main housing to the secondary housing. The securing means could of course also

take the form of adhesives, screws, and numerous other mechanical fastening arrangements known to those skilled in the art, all of which are to be considered equivalent for purposes of the invention.

Finally, as shown in Figures 7 and 9A-9G, horizontal bores (not shown) extending rearwardly from the LED openings are included in both the main and secondary housings to permit passage of the LED leads 156. At the rear of the secondary housing, leads 156 are bent either downward for passage through openings 157 in the secondary housing and openings 158 in the base to permit electrical connection of the LEDs to the circuit board or connected to contacts 156' of the type shown in Figure 8, which are inserted through openings 157 and 158. In addition, base 131 and/or main housing 132 may include conventional board locks 159 to facilitate attachment of the base and/or main housing to the circuit board on which the connector is mounted.

It will of course be appreciated by those skilled in the art that the inclusion of such features as LEDs and board locks are not essential to the invention, and may be omitted without departing from the scope of the invention. In addition, the position of the LED leads as well as the other pins on the base module may be varied as necessary to achieve desired connections within the spirit of the invention.

In the third preferred embodiment of the invention, illustrated in Figures 12A-12B, 13, and 14A-14C, the mating contacts 160 are mounted in the main housing 161 in conventional fashion by means of passages 161' and lip 161", and the transformers and chokes are mounted on a spindle 162 extending horizontally from the rear wall 163 of the connector secondary housing 164 to reduce the overall length of the connector structure. In this embodiment, passages 165 for the leads 166 of LEDs 167 are provided in the main housing rather than in the secondary housing, while the secondary housing includes a base extension 168 having slots 169 to accommodate the downwardly extending portions of contacts 160 and slots 170 for the transformer contacts 171. Also included in the secondary housing are flanges 172 and 173 for interengagement with the main housing 161 in order to secure the secondary housing to the main housing, and board locks 174.

The fourth preferred embodiment of the invention, illustrated in Figures 15, 16, 17A, and 17B is identical to the third preferred embodiment, except that the support structure for mating contacts 160, including passages 160' and lip 160", is provided on the extension 168' of the secondary housing 164', in a manner similar to front portion 140 of the second preferred embodiment of the invention, with alignment between the main housing portion 161' and secondary housing portion 164' being provided by

ribs 175 on extension 168' and grooves 176 in the main housing. This embodiment also includes tabs 177 for cooperation with slots (not shown) in the main housing to secure the secondary housing to the main housing. Again, a spindle is provided to support the transformers and chokes, and the passages for vertical extension of the LED leads are provided in the main housing rather than secondary housing, so that the side view of the main housing shown in Figure 12A and the front view of the secondary housing shown in Figure 14C are also applicable to this embodiment. While the LED leads 166 extend downward through the main housing as in the third preferred embodiment of the invention, however, in this embodiment, the leads also extend through openings 178 in the floor of the secondary housing.

The fifth preferred embodiment of the invention, illustrated in Figures 19A and 19B is identical to that of the first preferred embodiment of the invention, except that the inductor/filter structure 80 and 81 as well as transformers 80' and 81' are mounted vertically in the secondary housing. Similarly, the sixth preferred embodiment of the invention (Figures 20A-20B) is similar to that of the fifth preferred embodiment except that the secondary housing is formed from two parts 182 and 183 and includes vertical spindles 184 and 185 for respectively horizontally mounting the transformers 180' and 181' and inductor structures 180 and 181.

Finally, the seventh preferred embodiment of the invention uses a base and housing structure similar to that of the second preferred embodiment of the invention, including a base 131', main housing 132, and secondary housing 133. Main housing 132 and secondary housing 133 may be identical to the corresponding elements of the first preferred embodiment, except that the length of secondary housing 133 is reduced by amount corresponding to the reduction in length of the base 131' relative to base 131, achieved by modifying base 131 of the second preferred embodiment to include stepped component mounting posts 186 which permit stacking of transformers 124 and 124' above chokes 120 and 121. In addition, the embodiment illustrated in Figures 20A, 20B, and 21-23 utilizes a bent structure for the LED leads 156, in which the leads initially extend rearwardly from the rear of main housing 132 and are bent over LED supports 187 extending upwardly from base 131' to fit through openings 158 in the base during assembly of the base to the main housing, and before assembly of the secondary housing 133 to the main housing to complete the connector. It will of course be appreciated that the stepped post structure of this embodiment may be used with the LED lead structure of the second preferred embodiment, or in connection with any of the third through sixth preferred embodiments of the invention, and that the LED lead structure of this embodiment may also be used with any of the second through sixth embodiments of the invention.

Those skilled in the art will also appreciate that the front-to-rear dimension of the interior of the secondary housing in the second through seventh embodiments of the invention may be larger than that of the corresponding chamber in the conventional connector illustrated in Figure 1C so as to accommodate additional cores. In general, at least in interface cards, it is the width and height of the connector that is more limited than the depth, and thus there is some freedom to adjust the dimensions of the connector as necessary. It will further be appreciated by the skilled artisan that the illustrated design could easily be adapted for use with contacts arranged to extend from the top rather than the bottom of the plug receiving chamber.

Assembly of the illustrated connector simply involves winding the appropriate core structures, positioning the core structures on the base module of the connector or on the base of the secondary housing and positioning the base module within the secondary housing, if applicable, connecting the leads of the windings to terminals on the base or in the secondary housing, and securing the main and secondary housings together (and adding LEDs if desired), with the base captured in between in the case of the embodiment of Figure 3.

Having thus described a preferred embodiment of the invention with sufficient particularity to enable those

skilled in the art to easily make and use the invention, and having described several possible variations and modifications of the preferred embodiment, it should nevertheless be appreciated that still further variations and modifications of the invention are possible, and that all such variations and modifications should be considered to be within the scope of the invention. For example, in the variations of the first embodiment illustrated in Figures 4 and 5, it may be desirable to reduce the total number of ferrite cores, to add an additional common mode choke on the PCB side of the circuit, or to add other additional circuit components. Also, the base module of the connector in any of the second through seventh illustrated embodiments could be separate or integral with the secondary housing. Also, instead of mounting the cores on the base of the connector or on a spindle, the cores could be mounted on a printed circuit board within the connector, the general concept of using the connector itself to secure the cores could be extended to apply to filters other than the exemplary filter illustrated in the drawings, and other circuit elements could be added to the illustrated circuits.

Accordingly, the scope of the invention should not be limited by the above description, but rather should be interpreted solely in accordance with the appended claims.

I claim:

1. A common mode filter suitable for use in an electrical connector, comprising:

a first core structure including a pair of core legs connected by an end cap, said pair of core legs of the first core structure being hereinafter referred to as the first and second core legs;

a second core structure including a pair of core legs also connected by an end cap, said pair of core legs of the second core structure being hereinafter referred to as the third and fourth core legs;

a first winding including a coil section wrapped around the first core leg; and

a second winding including a first coil section wrapped around the second core leg, a second coil section wrapped around the third coil leg, and a third coil section wrapped around the fourth coil leg, said first winding coil and the first coil section of the second winding forming a transformer, and the second and third coil sections of the second winding forming a pair of choke coils of a common mode filter.

2. A filter as claimed in claim 1, wherein the ends of the second winding are shaped to form mating sections of a pair of RJ contacts.

3. A filter as claimed in claim 1, wherein the ends of the first winding are shaped for electrical connection to a printed circuit board.

4. A filter as claimed in claim 1, wherein the first coil section and the second coil section of the second winding are connected to each other through said circuit board.

5. A filter as claimed in claim 1, wherein said core members are formed by a pair of legs and a pair of end caps to form a closed loop.

6. An electrical connector having positioned therein a common mode filter, comprising:

an electrical connector housing having an opening arranged to receive a mating connector;

a first core structure positioned within the housing, including a pair of core legs connected by an end cap, said pair of core legs of the first core structure being hereinafter referred to as the first and second core legs;

a second core structure positioned within the housing, including a pair of core legs also connected by an end cap, said pair of core legs of the second core structure being hereinafter referred to as the third and fourth core legs;

a first winding having ends arranged to engage contacts of a mating connector which has been inserted into said opening, and a coil section wrapped around the first core leg; and

a second winding having ends extending from said housing, a first coil section wrapped around the second core leg, a second coil section wrapped around the third coil leg, and a third coil section wrapped around the fourth coil leg, said first winding coil and the first coil section of the second winding forming a transformer, and the second and third coil sections of the second winding forming a pair of choke coils of a common mode filter.

7. A connector as claimed in claim 6, wherein the first ends of the second winding are shaped to form mating sections of a pair of RJ contacts.

8. A connector as claimed in claim 6, wherein the ends of the first winding are shaped for electrical connection to a printed circuit board.

9. A filter as claimed in claim 1, wherein the first coil section and the second coil section of the second winding are connected to each other through said circuit board.

10. A connector as claimed in claim 6, wherein said core members are formed by a pair of legs and a pair of end caps to form a closed loop.

11. A connector as claimed in claim 6, further comprising a second transformer and a second common mode filter.

12. A connector as claimed in claim 11, wherein said second transformer includes an additional said first core structure.

13. An electrical connector, comprising:

a main electrical connector housing having an opening arranged to receive a mating connector;

a secondary connector housing;

means for securing the main electrical connector housing to the secondary connector housing;

a first core structure positioned within the secondary connector housing, said first core structure comprising a magnetic core having a winding; and

means including terminals fixed with respect to said main and secondary housings for electrically connecting said winding to PCB tails and to mating contacts of said connector.

14. A connector as claimed in claim 13, wherein said terminals are affixed to a base which is arranged to be secured to said main housing and said secondary housing during assembly of the connector.

15. A connector as claimed in claim 14, wherein said base includes ribs engageable with slots in said main and secondary housings to align said base with said main and secondary housings.

16. A connector as claimed in claim 15, wherein said base is integral with said secondary housing.

17. A connector as claimed in claim 15, wherein said mating contacts are RJ contacts having mating sections extending obliquely into said opening, horizontal sections extending from the mating sections through passages in said base, and vertical sections extending from the horizontal sections.

18. A connector as claimed in claim 15, wherein said vertical sections of some of said contacts form PCB tails and vertical sections of others of said contacts extend upwardly to form terminals for connections to said component.

19. A connector as claimed in claim 13, wherein said mating contacts are RJ contacts having mating sections extending obliquely into said opening, horizontal sections extending from the mating sections through passages in said base, and vertical sections extending from the horizontal sections.

20. A connector as claimed in claim 13, wherein said secondary housing includes means for supporting said first core structure.

21. A connector as claimed in claim 20, wherein said first core structure is a transformer core.

22. A connector as claimed in claim 13, wherein said first core structure is a transformer and further comprising a choke coil structure positioned in said secondary housing, a winding of said choke coil also being electrically connected to said terminals.

23. A connector as claimed in claim 22, wherein said transformer and choke coils are positioned such that axes of said coils are vertical.

24. A connector as claimed in claim 22, wherein said transformer and choke coils are positioned such that axes of said coils are horizontal.

25. A connector as claimed in claim 13, wherein said mating contacts are supported by said main housing.

26. A connector as claimed in claim 13, wherein said mating contacts are supported by an extension of said secondary housing.

27. A connector as claimed in claim 13, further comprising at least one LED visible from a front of said main housing and having leads extending through said main housing.

28. A connector as claimed in claim 27, wherein said leads of the LED also extend through the secondary housing to form PCB tails extending from a bottom of the secondary housing.

29. A connector as claimed in claim 13, wherein said secondary housing includes top and bottom halves having respective downward and upward extensions which cooperate to form a spindle for said first core structure when the top and bottom halves are assembled together to form the secondary housing.

FIG. 1A
PRIOR ART

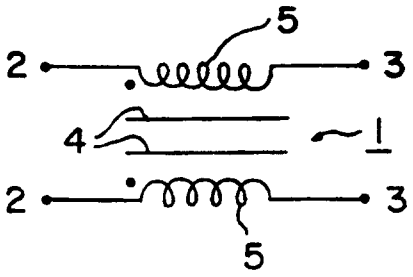


FIG. 1B
PRIOR ART

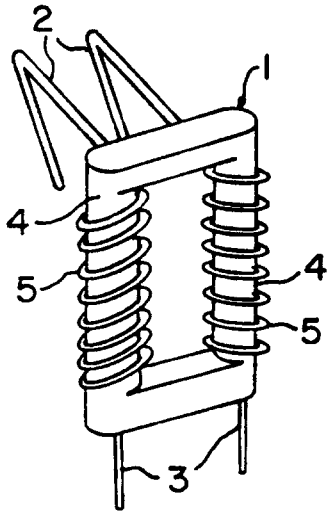


FIG. 1C
PRIOR ART

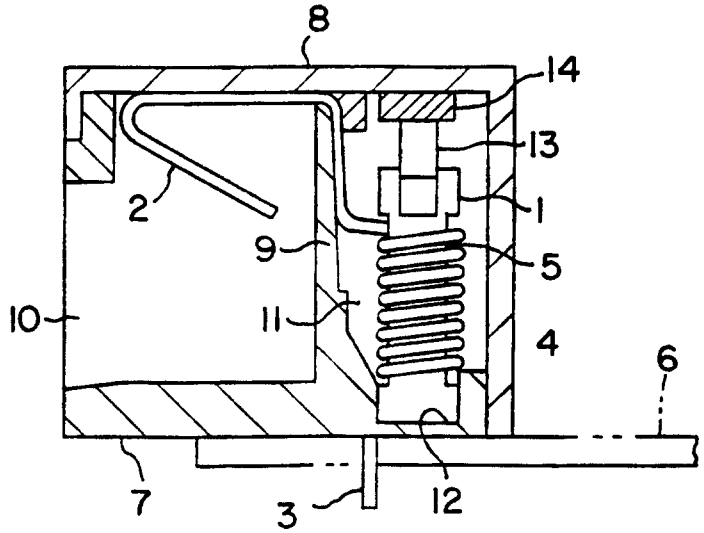


FIG. 2

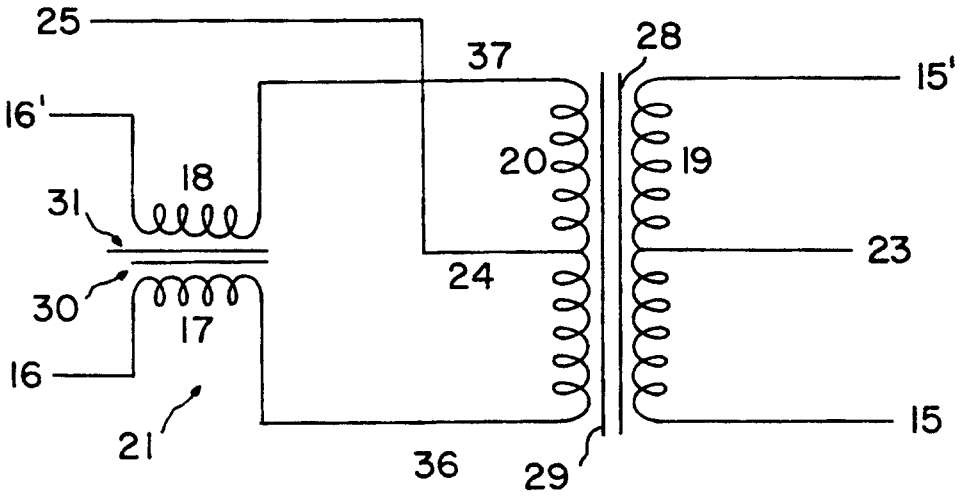


FIG. 3

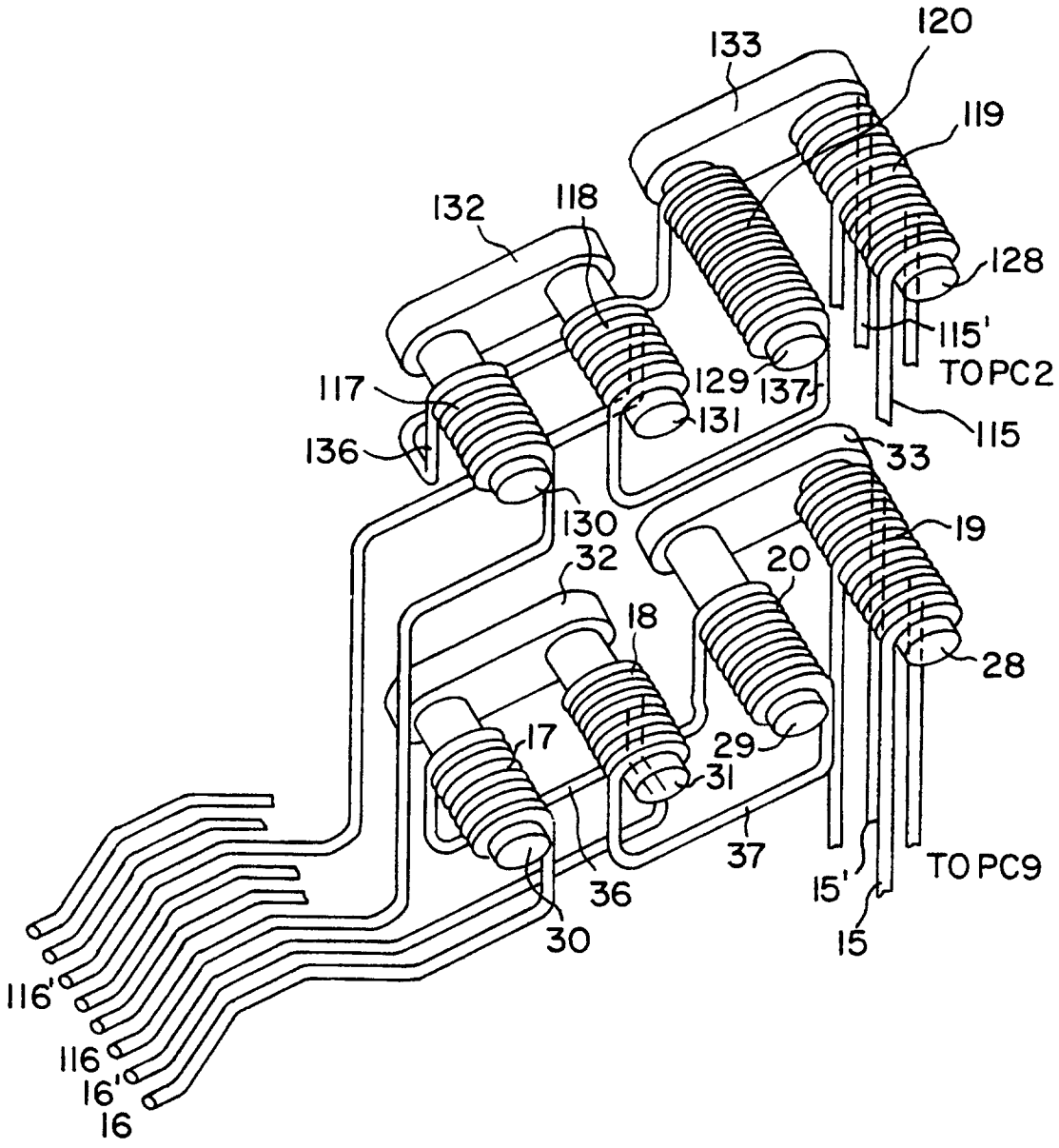

120
133
119
132
118
128
115'
TO PC2
117
129
137
131
115
136
33
130
19
32
20
18
28
17
29
31
37
TO PC9
36
15'
30
15
116'
116
16'
16

FIG. 4

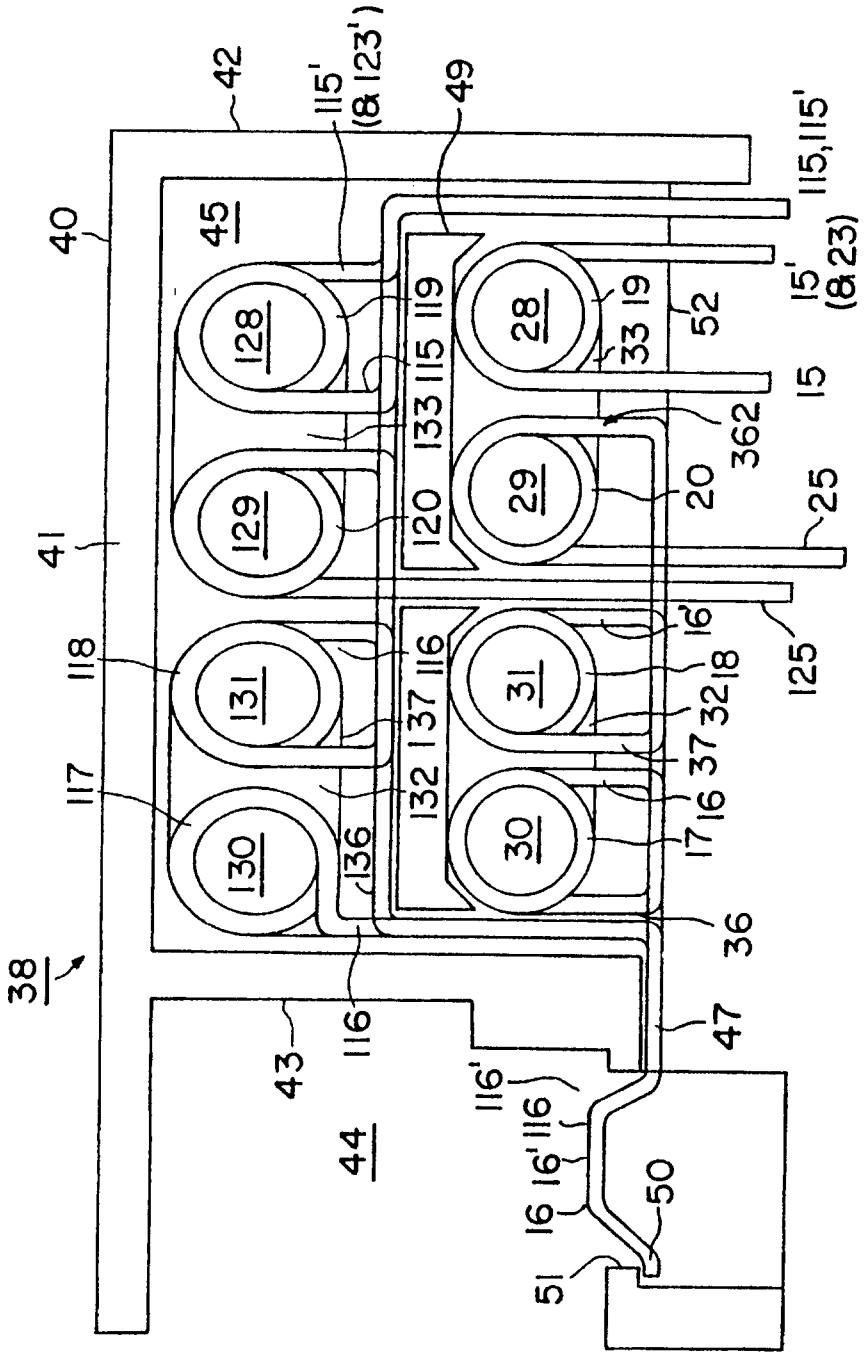
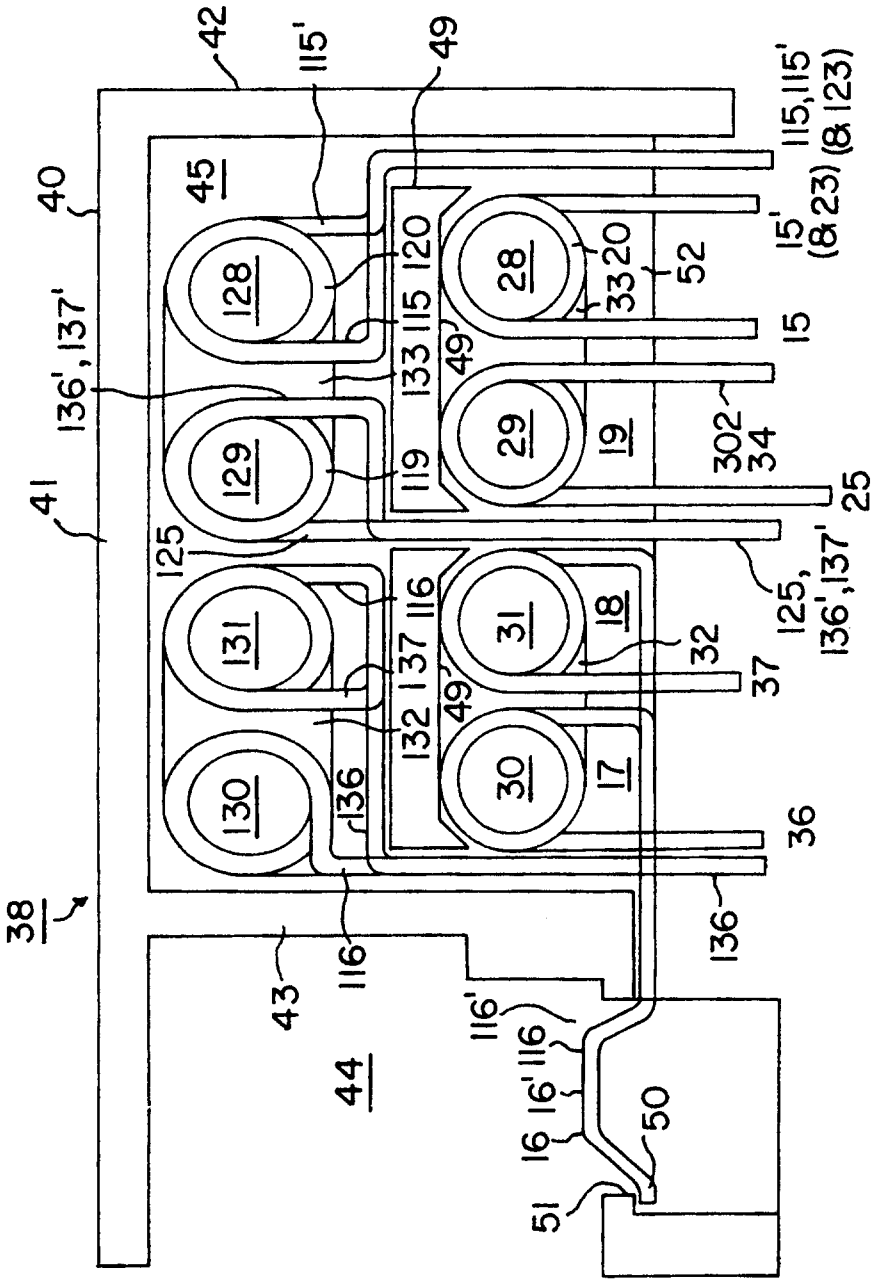

42
115'
(& 123')
49
115,115'
40
45
15'
(& 23)
128
119
28
33 19
52
115
15
133
362
129
120
29
20
25
41
16'
118
116
131
31
18
125
137
32
37
117
132
16
130
136
30
17
36
38
43
116
47
116'
44
116
16'
16
50
51

FIG. 5


42
115'
49
115,115'
(&123)
40
45
15'
(&23)
120
28
3320
52
128
115
133
49'
15
136',137'
29
19
302
34
129
119
41
25
125
125,
136',137'
116
31
18
32
131
137
37
49'
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17
136
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38
43
116
136
116'
116'
44
16'
16
50
51

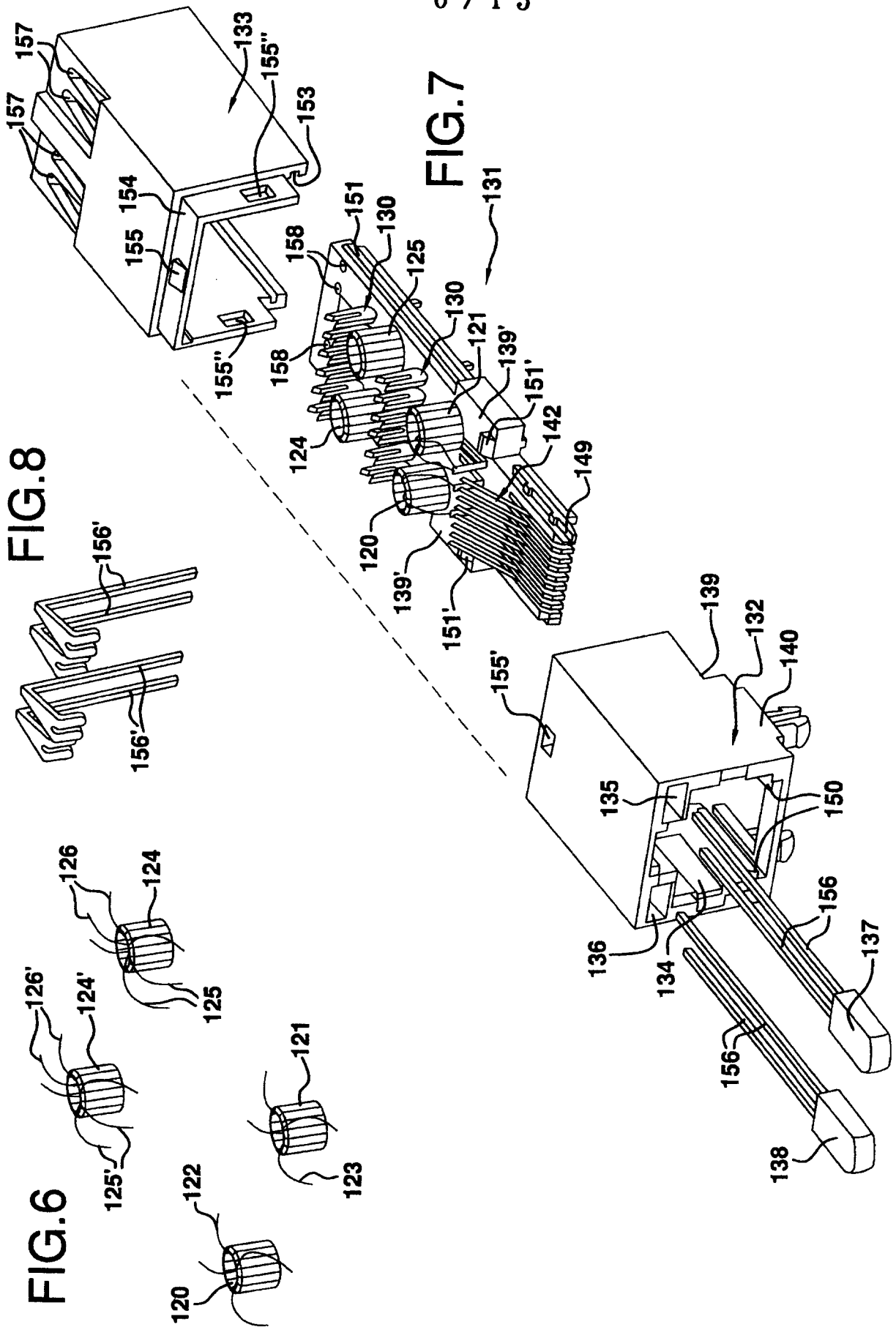


FIG.6
FIG.7
FIG.8
157
157
133
155''
153
154
155
158
151
130
125
131
155''
158
130
121
139'
151'
124
142
149
120
139'
151'
139
132
140
155'
135
150
136
134
156
137
156
138
156'
156'
126
124
125
126'
124'
125'
121
123
122
120

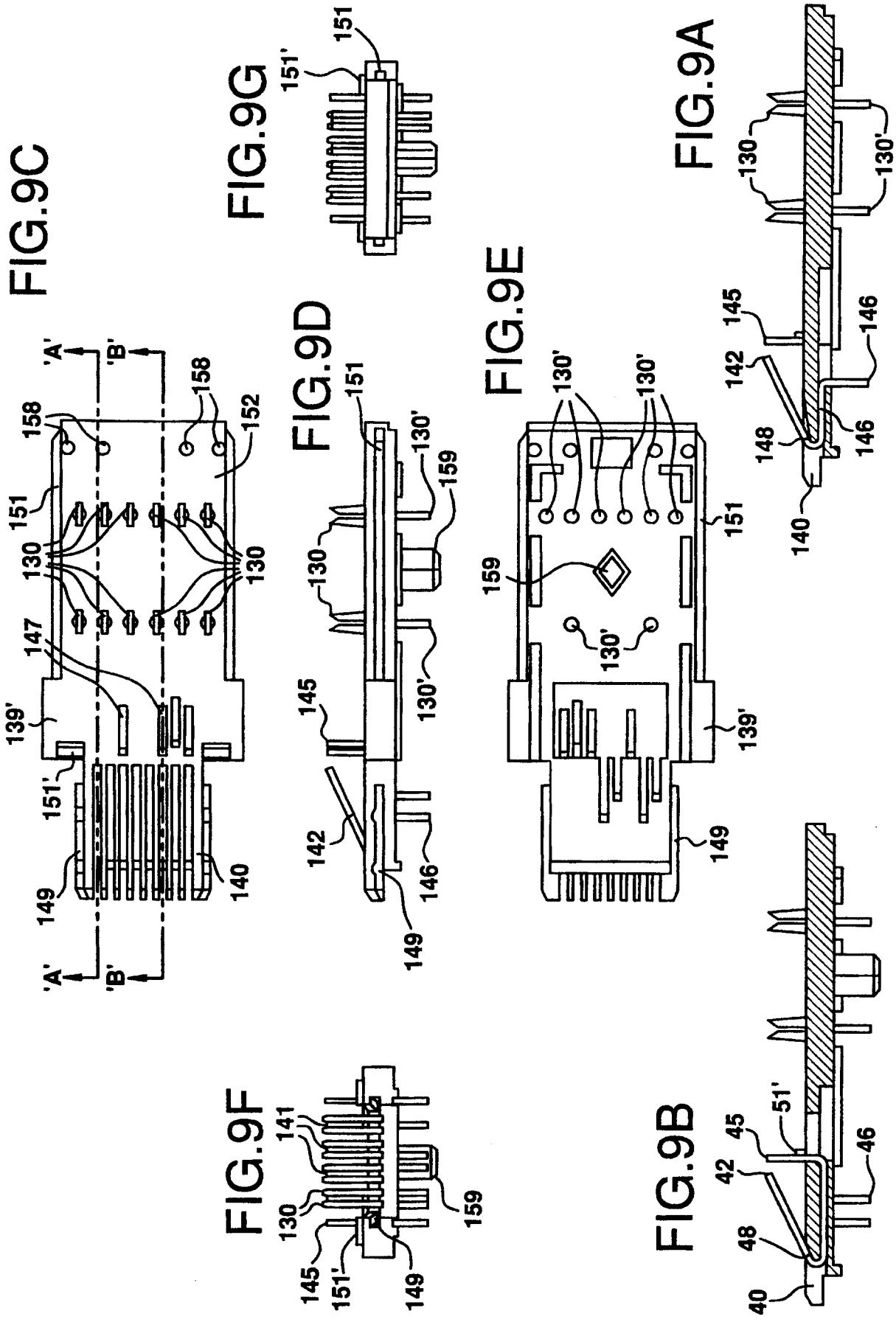


FIG.9C
FIG.9G
FIG.9D
FIG.9E
FIG.9A
FIG.9F
FIG.9B

FIG. 11

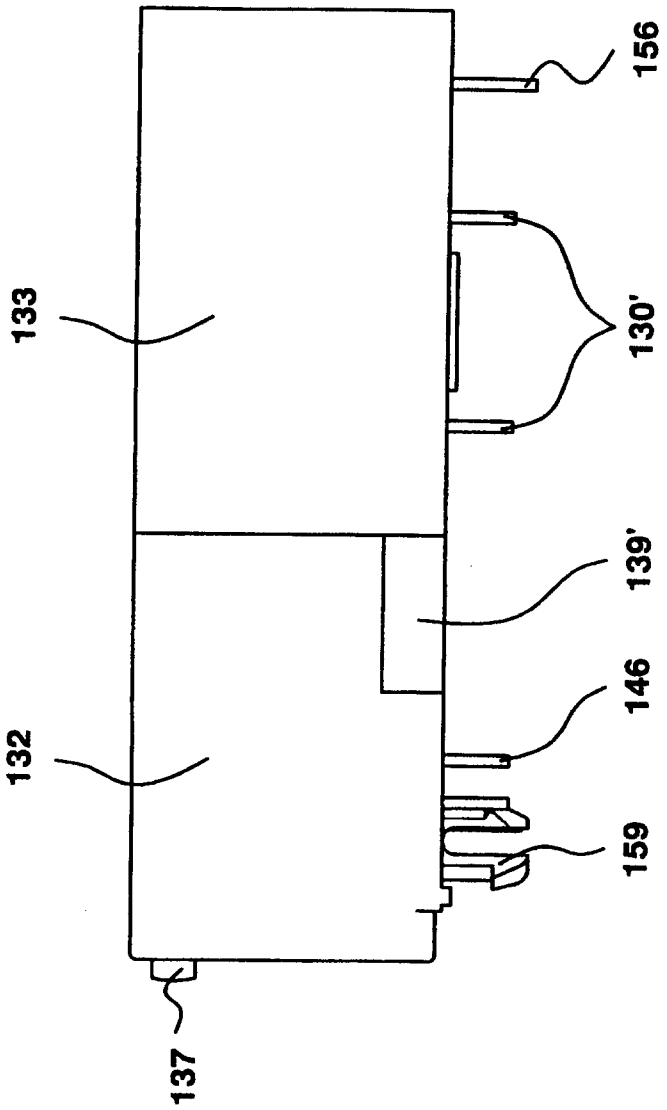

156
133
130'
139'
146
132
159
137

FIG. 10

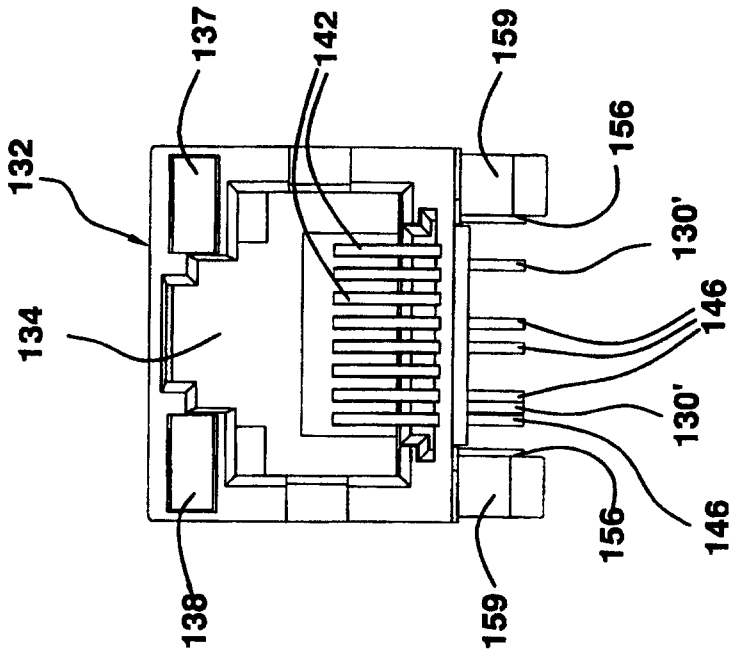

137
142
159
132
156
130'
134
146
130'
156
146
138
159

FIG. 14C

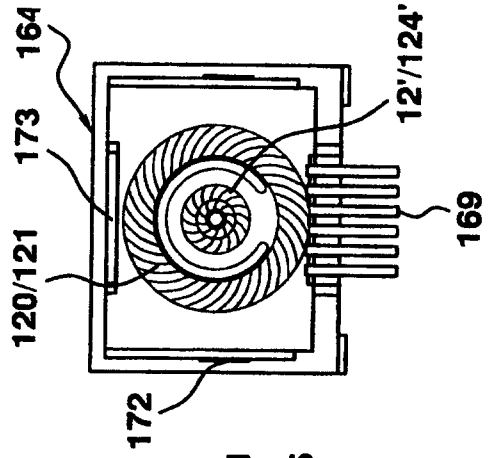


FIG. 14A

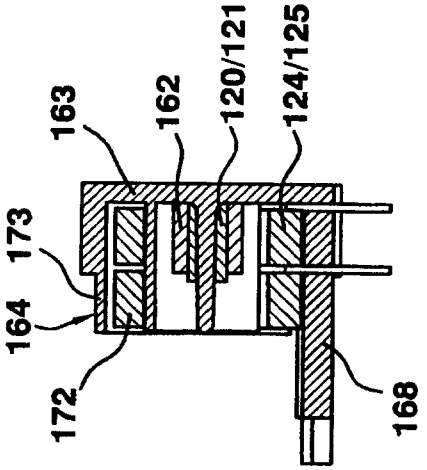


FIG. 14B

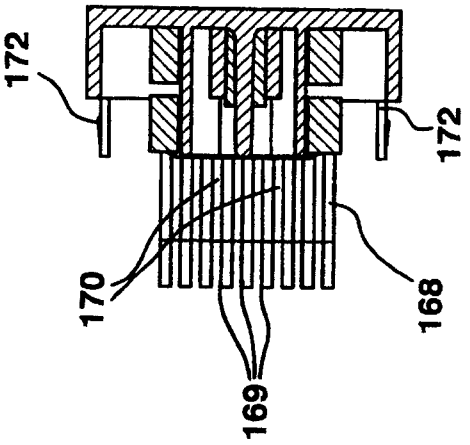


FIG. 13

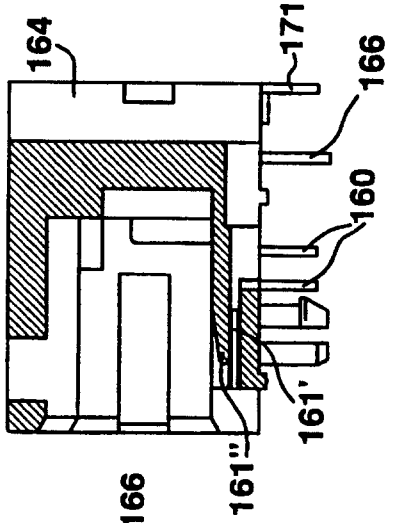


FIG. 12A

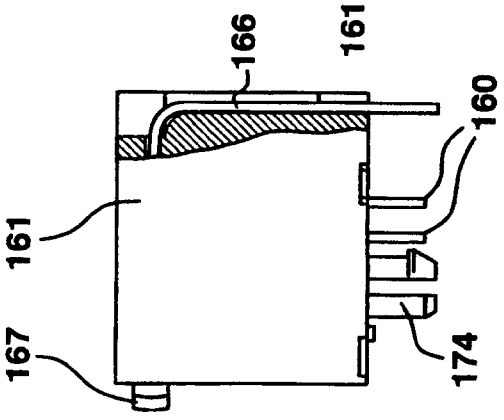
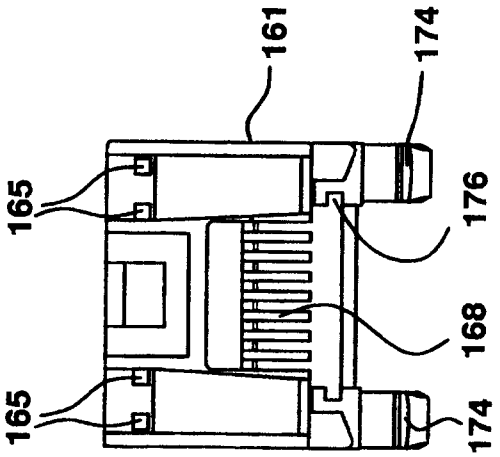


FIG. 12B



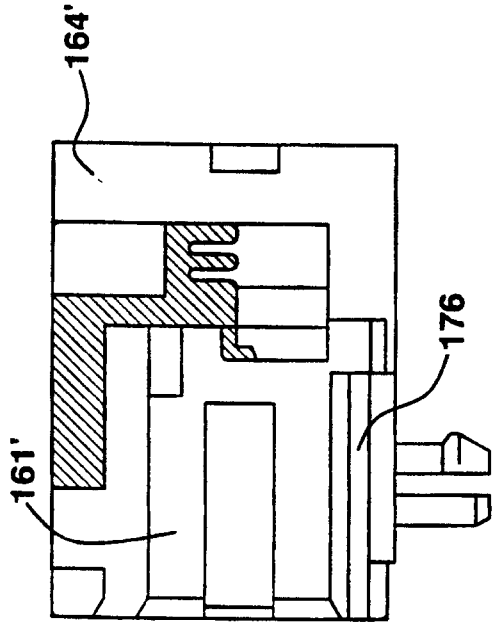


FIG. 16

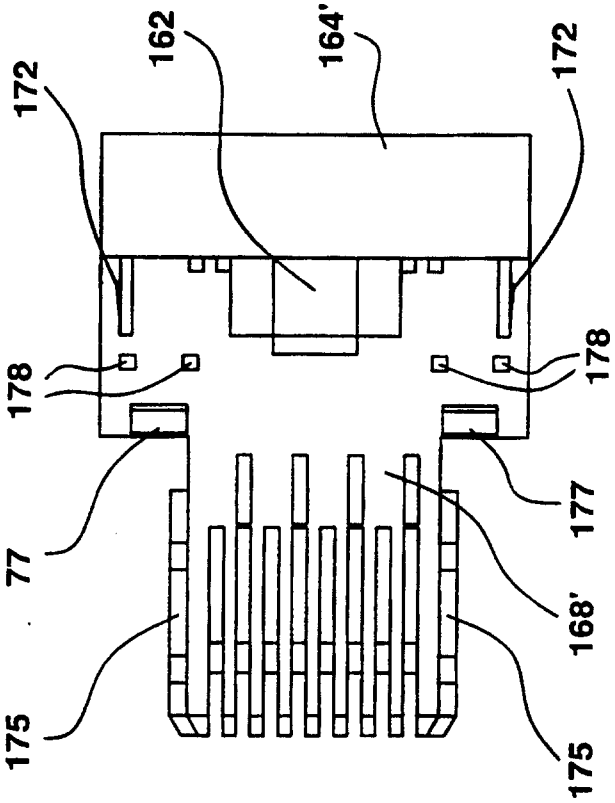


FIG. 17B

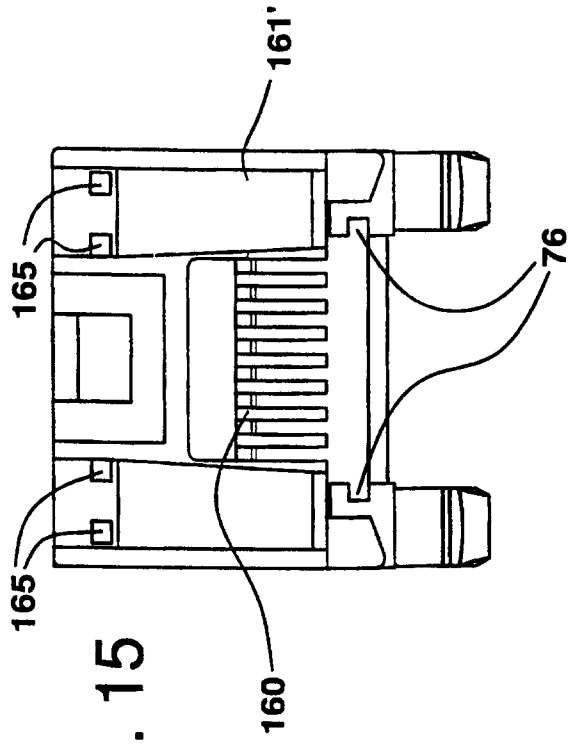


FIG. 15

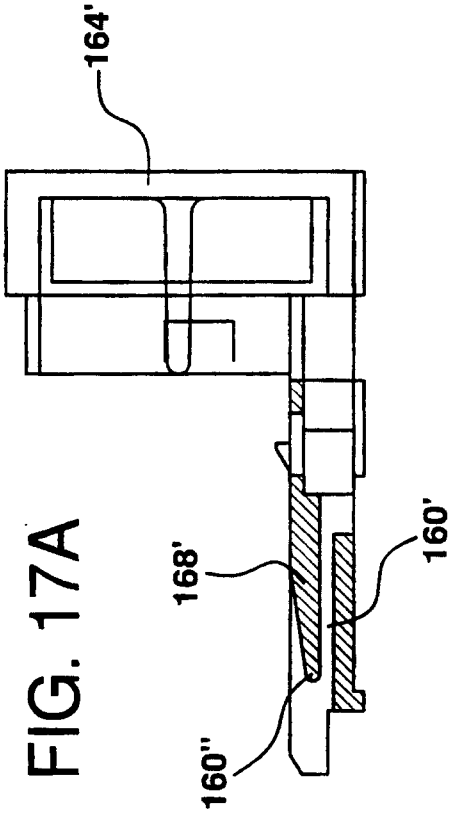


FIG. 17A

FIG. 18A

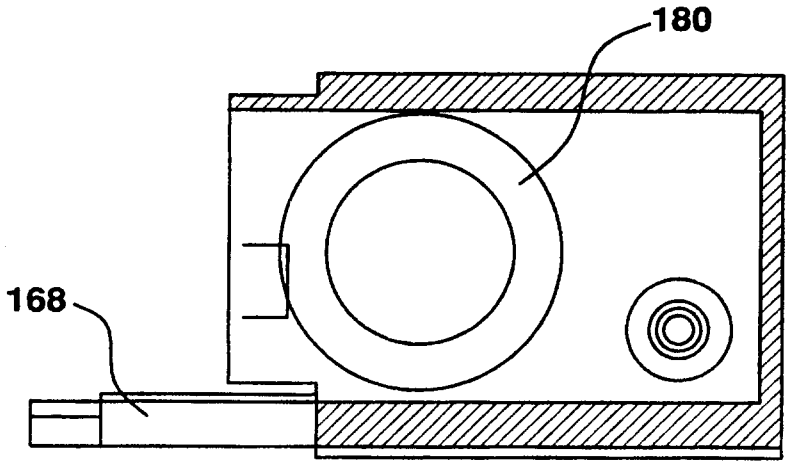


FIG. 18B

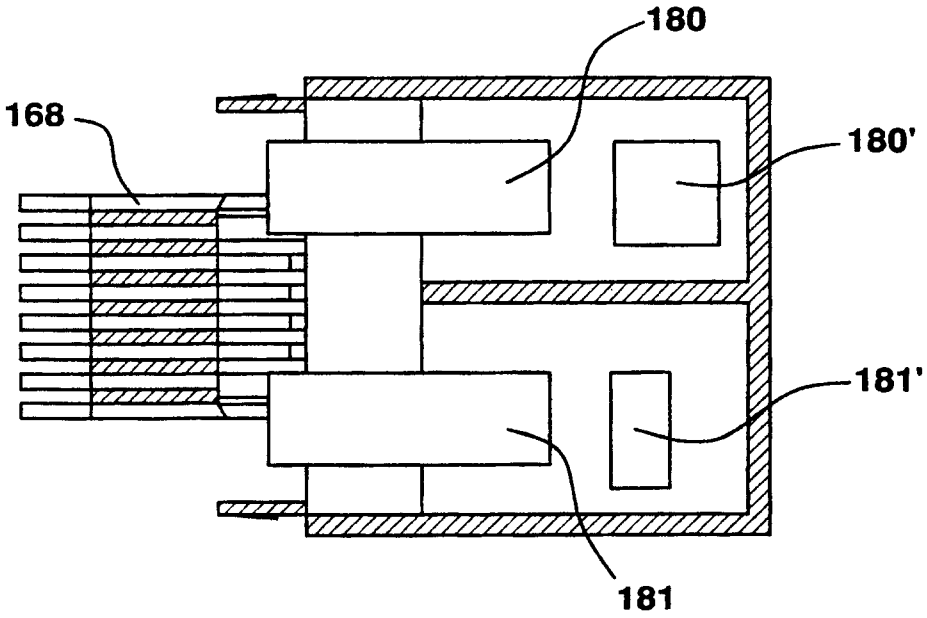


FIG. 19A

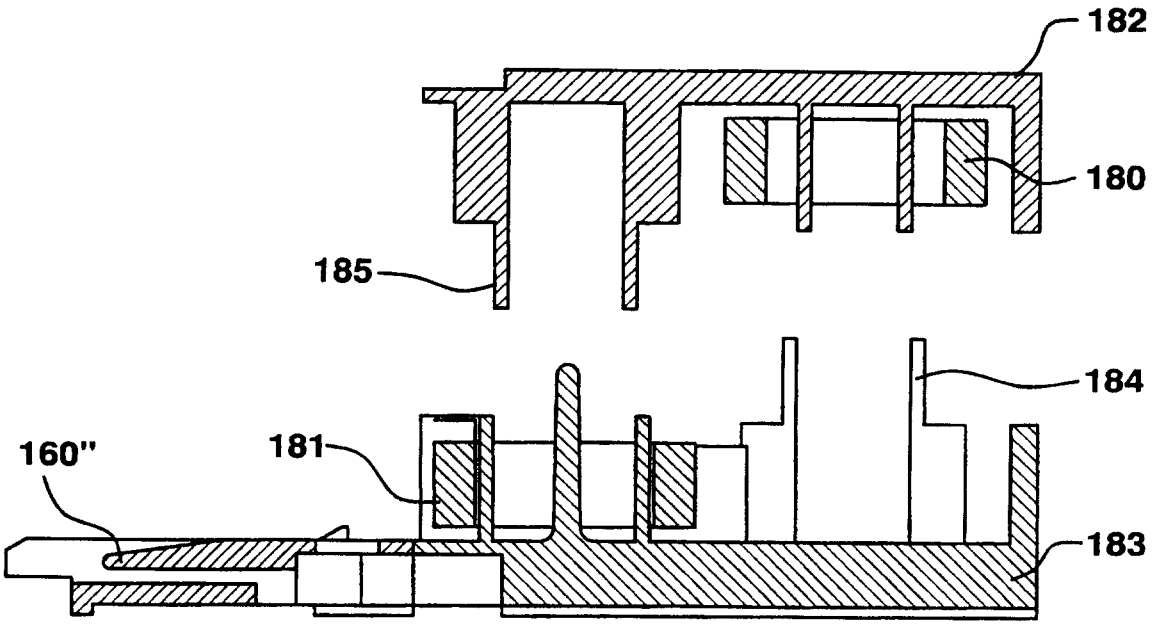


FIG. 19B

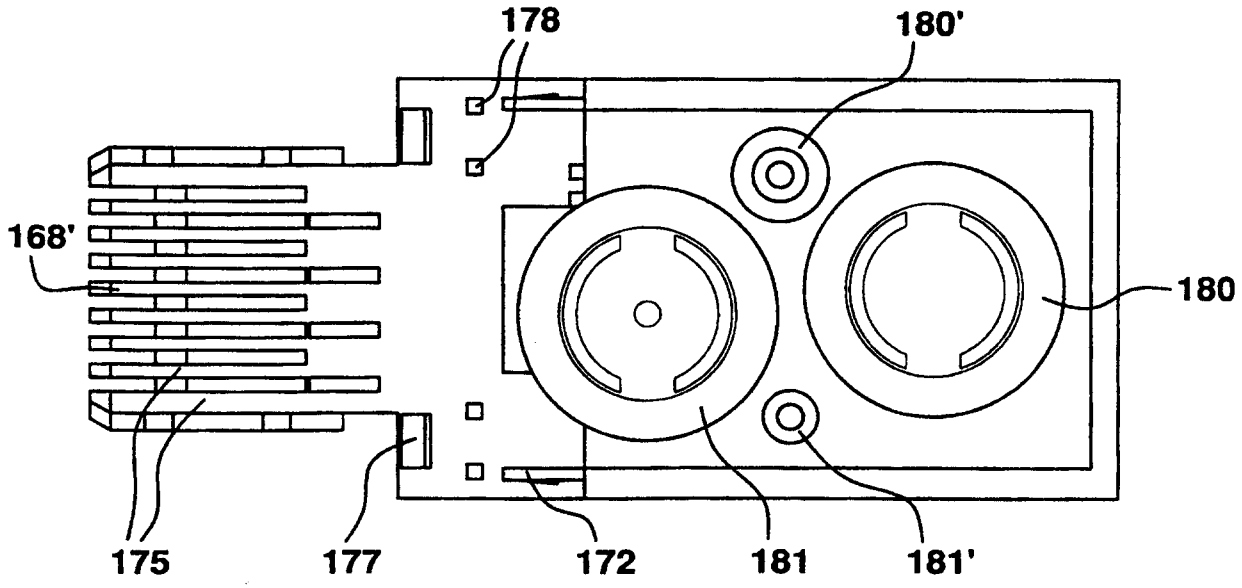


FIG.20A

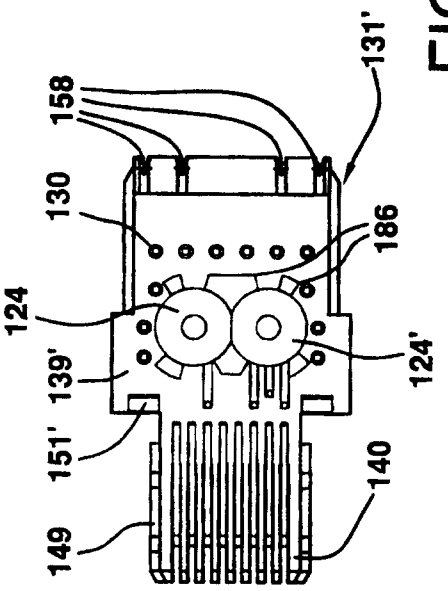


FIG.23

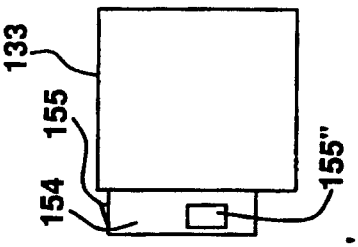


FIG.20B

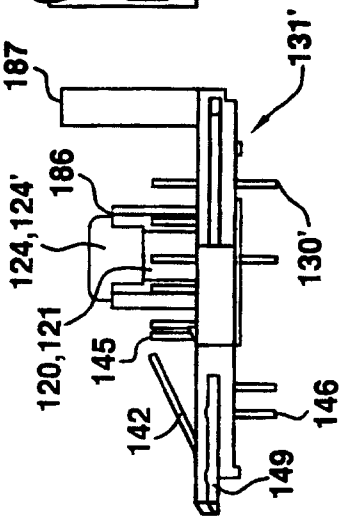


FIG.22

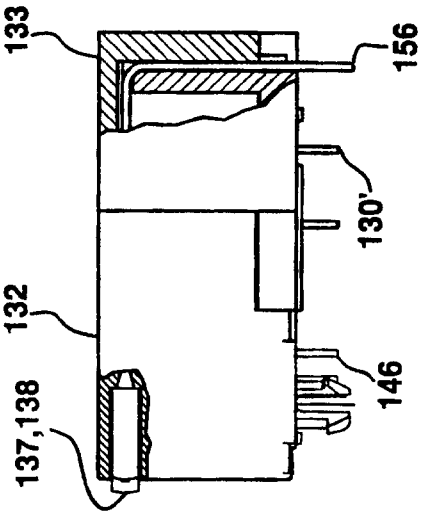
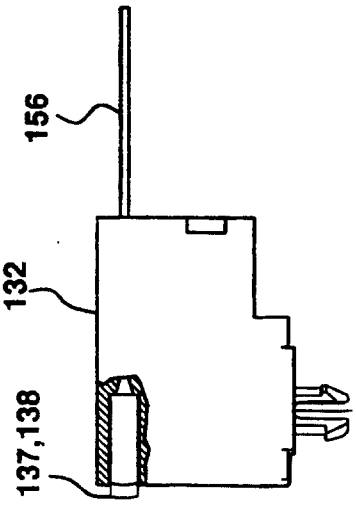
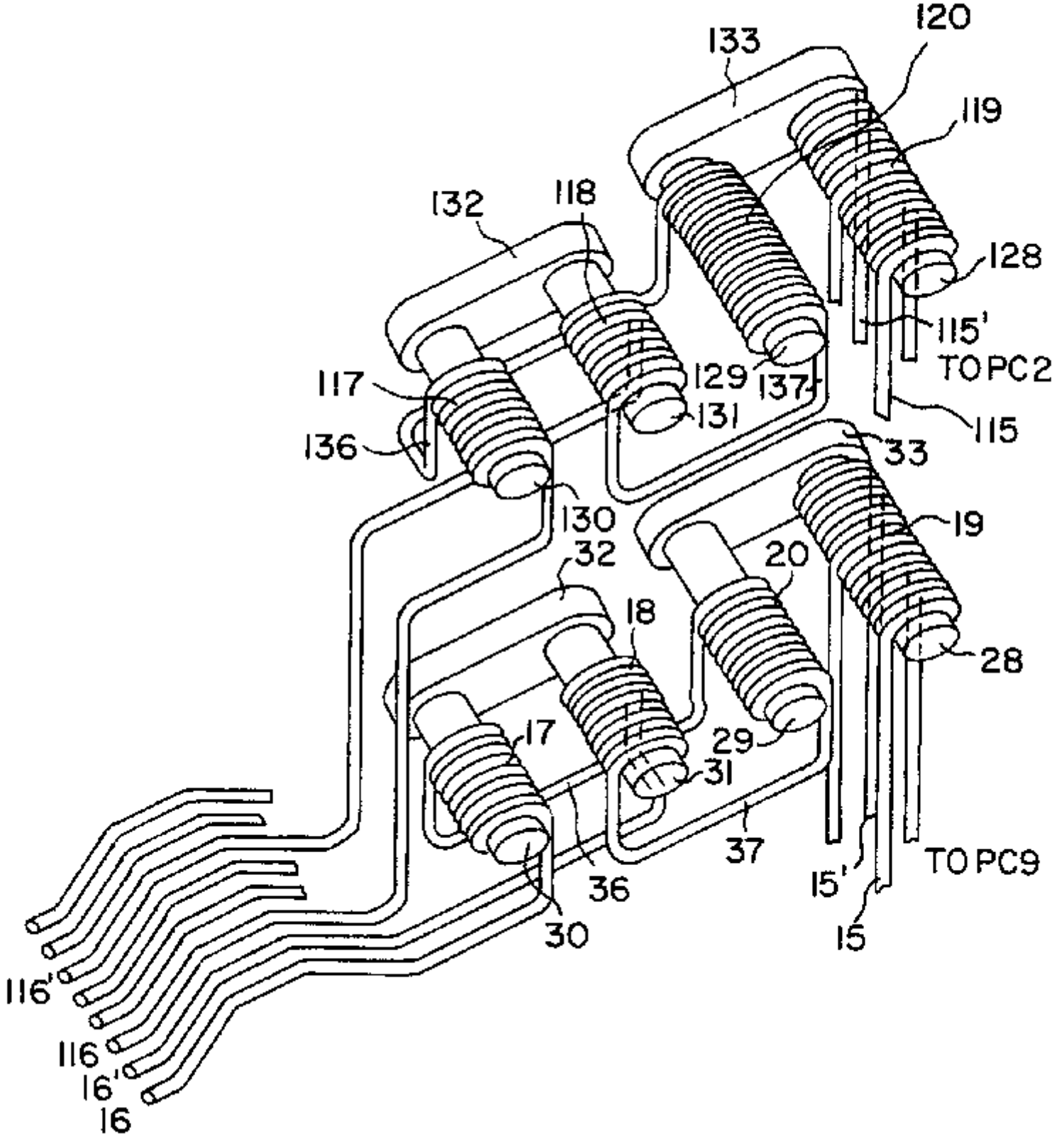


FIG.21




120
133
119
132
118
128
115'
TO PC2
129
137
117
131
115
136
33
130
19
32
20
18
28
17
29
31
37
TO PC9
36
15'
30
15
116'
116
16'
16