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Electronic assembly having a cable connector module

Abstract

An electronic assembly includes a socket assembly including a cage mounted to a circuit board and a socket connector received in a cavity of the cage. The socket connector includes a substrate holding interposer contacts with compressible upper and lower contact portions. The electronic assembly includes a cable connector module received in the cavity of the cage and coupled to the socket connector. The cable connector module includes a housing coupled to the cage, a circuit card received in the cavity of the housing, and cable assemblies coupled to the circuit card. The circuit card is coupled to the socket connector.

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Background/Summary

BACKGROUND OF THE INVENTION

(1) The subject matter herein relates generally to communication systems.

(2) There is an ongoing trend toward smaller, lighter, and higher performance communication components and higher density systems, such as for ethernet switches or other system components. Typically, the system includes an electronic package coupled to a circuit board, such as through a socket connector. Electrical signals are routed between the electronic package and the circuit board. The electrical signals are then routed along traces on the circuit board to another component, such as a transceiver connector. The long electrical paths through the host circuit board reduce electrical performance of the system. Additionally, losses are experienced between the connector interfaces and along the electrical signal paths of the transceivers. Conventional systems are struggling with meeting signal and power output from the electronic package. Some known systems utilize an electronic assembly having cable assemblies to transmit the signals along cables rather than signal traces along the host circuit board. However, the electronic assembly includes numerous cables terminated to a circuit card. There is a need to increase the density of the cables and the contact pads on the circuit card to reduce the overall size of the electronic assembly. However, there are limits to spacing of the contact pads to allow routing of the cables from the circuit card with conventional cable termination techniques. For example, ample spacing is needed between rows of the circuit cards to allow routing of the cables along the circuit card. Additionally, as data speeds increase, the grounding structure at the interface between the cables and the circuit card is proving ineffective, particularly at higher frequencies.

BRIEF DESCRIPTION OF THE INVENTION

(3) In one embodiment, an electronic assembly is provided and includes a socket assembly including a cage configured to be mounted to a circuit board. The cage having a cavity. The socket assembly includes a socket connector received in the cavity of the cage. The socket connector includes a substrate holding interposer contacts. Each interposer contact includes an upper contact portion and a lower contact portion. The upper contact portion is compressible. The lower contact portion is compressible. The lower contact portion is terminated to a board contact of the circuit board. The electronic assembly includes a cable connector module received in the cavity of the cage and coupled to the socket connector. The cable connector module includes a housing having a cavity. The housing is coupled to the cage. The cable connector module includes a circuit card held by the housing. The circuit card has signal contact pads at an upper surface of the circuit card and mating contact pads at a lower surface of the circuit card. The mating contact pads are coupled to the upper contact portions of corresponding interposer contacts. The signal contact pads are arranged in pairs in a plurality of rows. The cable connector module includes cable assemblies coupled to the circuit card.

(4) In another embodiment, an electronic assembly is provided and includes a socket assembly including a cage configured to be mounted to a circuit board. The cage has walls extending between a top and a bottom of the cage. The walls define a cavity. The socket assembly includes a socket connector received in the cavity at the bottom of the cage. The socket connector is configured to be mounted to the circuit board. The socket connector includes a substrate holding interposer contacts. Each interposer contact includes an upper contact portion and a lower contact portion. The lower contact portion is terminated to a board contact of the circuit board. The

electronic assembly includes a cable connector module received in the cavity of the cage and coupled to the socket connector. The cable connector module includes a housing having a cavity. The cable connector module includes a circuit card held by the housing. The circuit card having signal contact pads at an upper surface of the circuit card and mating contact pads at a lower surface of the circuit card. The mating contact pads are coupled to the upper contact portions of corresponding interposer contacts. The signal contact pads are arranged in pairs in a plurality of rows. The cable connector module includes cable assemblies coupled to the circuit card. The electronic assembly includes a spring clip coupled to the walls of the cage. The spring clip engages the cable connector module to hold the cable connector module in the cavity of the cage. The spring clip presses the cable connector module into the socket connector to mate the mating contact pads with the upper contact portions of the interposer contacts.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a front perspective view of a communication system having an electronic assembly in accordance with an exemplary embodiment.

(2) FIG. **2** is a rear perspective view of a communication system having an electronic assembly in accordance with an exemplary embodiment.

(3) FIG. **3** is an exploded view of the communication system in accordance with an exemplary embodiment showing the electronic assembly and the circuit board.

(4) FIG. **4** is a bottom perspective view of the cable connector module **104** in accordance with an exemplary embodiment.

(5) FIG. **5** is a top perspective view of a portion of the cable connector module in accordance with an exemplary embodiment.

(6) FIG. **6** is a perspective view of the cable in accordance with an exemplary embodiment.

(7) FIG. **7** is a perspective view of the conductor support in accordance with an exemplary embodiment.

(8) FIG. **8** is a perspective view of the bottom ground rake in accordance with an exemplary embodiment.

(9) FIG. **9** is a perspective view of the top ground hood in accordance with an exemplary embodiment.

(10) FIG. **10** is a perspective view of a portion of the cable connector module in accordance with an exemplary embodiment.

(11) FIG. **11** is a top perspective view of a portion of the cable connector module in accordance with an exemplary embodiment.

(12) FIG. **12** is a rear perspective view of a portion of the cable connector module in accordance with an exemplary embodiment.

(13) FIG. **13** is a side view of a portion of the cable connector module in accordance with an exemplary embodiment.

(14) FIG. **14** is a top perspective view of a portion of the cable connector module in accordance with an exemplary embodiment.

(15) FIG. **15** is a cross sectional view of the communication system in accordance with an exemplary embodiment showing the electronic assembly and the circuit board.

(16) FIG. **16** is a cross sectional view of the communication system in accordance with an exemplary embodiment showing the electronic assembly and the circuit board.

DETAILED DESCRIPTION OF THE INVENTION

(17) FIG. **1** is a front perspective view of a communication system **100** having an electronic assembly **102** in accordance with an exemplary embodiment. FIG. **2** is a rear perspective view of a

communication system **100** having an electronic assembly **102** in accordance with an exemplary embodiment. The electronic assembly **102** includes one or more socket assemblies **108** and corresponding cable connector modules **104** (one set shown in FIGS. **1** and **2**). The socket assembly **108** is used to electrically connect the corresponding cable connector module **104** to a circuit board **110**. An electronic package **106** is electrically connected to the circuit board **110**. The cable connector modules **104** are electrically connected to the electronic package **106** through the socket assemblies **108** and the circuit board **110**.
(18) One electronic assembly **102** (socket assembly **108** and corresponding cable connector module **104**) is shown on one side of the electronic package **106** in FIGS. **1** and **2**. However, it should be understood that electronic assemblies **102** may be provided at more than one side, such as all four sides, in alternative embodiments. In various embodiments, a plurality of electronic assemblies **102** may be provided at the side(s) of the electronic package **106**. In various embodiments, the cable connector modules **104** are electrical modules using electrical conductors to transmit electrical data signals.
(19) In various embodiments, the electronic package **106** may be an integrated circuit assembly, such as an ASIC. However, the electronic package **106** may be another type of communication component. The electronic package **106** may be mounted directly to the circuit board **110**. For example, the electronic package **106** may be soldered to the circuit board **110**.
(20) In an exemplary embodiment, compression elements are used to load the cable connector modules **104** against the socket assemblies **108** to electrically connect the cable connector modules **104** to the socket assemblies **108** and to electrically connect the socket assemblies **108** to the circuit board **110**. For example, the compression elements may include springs that press the components downward to load the socket assemblies **108** and create mechanical and electrical connections between the cable connector modules **104** and the socket assemblies **108**. In various embodiments, the cable connector modules **104** are individually clamped or compressed against the socket assemblies **108** by the compression elements and are thus individually serviceable and removable from the socket assemblies **108**.
(21) In an exemplary embodiment, the communication system **100** includes heat dissipating elements (not shown) to dissipate heat from the electronic package **106** and/or the cable connector modules **104**.
(22) FIG. **3** is an exploded view of the communication system **100** in accordance with an exemplary embodiment showing the electronic assembly **102** and the circuit board **110**. The electronic assembly **102** includes the cable connector module **104** and the socket assembly **108**. The socket assembly **108** is used to electrically connect the cable connector module **104** to the circuit board **110**. In the illustrated embodiment, the cable connector module **104** is an electrical module having a plurality of cables terminated within the cable connector module **104**.
(23) The circuit board **110** includes a mounting area **114** on an upper surface **116** of the circuit board **110**. The socket assembly **108** is coupled to the circuit board **110** at the mounting area **114**. The mounting area **114** may be located adjacent to the electronic package **106** (shown in FIG. **1**). The circuit board **110** includes board contacts (not shown) at the mounting area **114**. The board contacts are arranged in an array, such as in rows and columns. The board contacts may be pads or traces of the circuit board **110**. The board contacts may be high speed signal contacts, low speed signal contacts, ground contacts, or power contacts. The board contacts may include pairs of high-speed signal board contacts surrounded by a ring or fence of ground board contacts.
(24) In an exemplary embodiment, the cable connector module **104** includes a connector housing **220** holding a circuit card **302** and a plurality of cable assemblies **300** terminated to the circuit card **302**. Each cable assembly **300** includes a cable **310** and a support structure for the cable **310**. The support structure is used to couple an end of the cable **310** to the circuit card **302**. In an exemplary embodiment, the cable connector module **104** includes a cable holder **304** that holds the cable assemblies **300** relative to the circuit card **302**.

(25) The connector housing **220** includes a housing cavity **222** that holds the cable assemblies **300** and the circuit card **302**. The connector housing **220** may be a metal shell or cage that receives the cable assemblies **300**. Alternatively, the connector housing **220** may be a plastic molded component. In an exemplary embodiment, the housing **220** extends between a top **224** and a bottom **226**. The circuit card **302** is provided at the bottom **226**. The housing **220** extends between a front **230** and a rear **232**. The housing **220** includes sides **234** between the front **230** and the rear **232**. The housing includes latching features **235** at the sides **234**. The housing **220** includes a pocket **236** at the top **224**. The housing **220** may include guide ribs **237** at the top **224** that define the pocket **236**. The guide ribs **237** may be located at the front **230** and/or the rear **232** and/or the sides **234**. Optionally, at least one of the guide ribs **237** may be approximately centered along the top **224**.
(26) In an exemplary embodiment, the socket assembly **108** includes a cage **120** and a socket connector **122** arranged in a cavity **124** of the cage **120**. The cavity **124** receives the cable connector module **104** to mate with the socket connector **122** of the socket assembly **108**. The cage **120** guides mating of the cable connector module **104** with the socket connector **122**.
(27) In an exemplary embodiment, the cage **120** is a stamped and formed cage configured to be stamped and formed from a metal sheet. The cage **120** includes cage walls **240** defining the cavity **124**. The cage walls **240** extend between a top **242** and a bottom **244** of the cage **120**. The bottom **244** is configured to be coupled to the circuit board **110**. In an exemplary embodiment, the cage **120** includes mounting tabs **246** configured to be mounted to the circuit board **110**. The mounting tabs **246** may extend from the bottom **244**. The mounting tabs **246** may include openings configured to receive fasteners, such as threaded fasteners, used to couple the cage **120** to the circuit board **110**. Other types of mounting tabs may be used in alternative embodiments, such as press fit pins, weld tabs, solder tabs, slips, latches, threaded openings, or other types of mounting features. In alternative embodiments, separate securing features may be used to secure the cage **120** to the circuit board **110**. In an exemplary embodiment, the cage **120** includes a top opening **148** at the top **242**. The top opening **148** is configured to receive the cable connector module **104**. For example, the cable connector module **104** is top loaded into the cavity **124** through the top opening **148**.
(28) In an exemplary embodiment, the cage **120** includes side walls **250**, **252** and end walls **254**, **256**. The side walls **250**, **252** may be shorter than the end walls **254**, **256**. In the illustrated embodiment, the end wall **256** includes an opening **258**. The opening **258** is configured to receive a portion of the cable connector module **104**, such as the cables. In an exemplary embodiment, the cage **120** includes latching features **260** used for latchably coupling to the cable connector module **104**. For example, the latching features **260** interface with the latches **235** of the housing **220** of the cable connector module **104**. The latching features **260** may be deflectable latches. Other types of latching features may be used in alternative embodiments, such as latch openings. The latching features **260** are provided at the side walls **250**, **252** in the illustrated embodiment. However, the latching features **260** may be provided at other locations in alternative embodiments. In an exemplary embodiment, the cage **120** includes openings **262** in alternative embodiments. The openings **262** are provided at the side walls **250**, **252** in the illustrated embodiment. However, the openings **262** may be provided at other locations in alternative embodiments.
(29) In an exemplary embodiment, the electronic assembly **102** includes a spring clip **280** used to couple the cable connector module **104** to the socket connector **122**. The spring clip **280** is configured to engage the cable connector module **104** to hold the cable connector module **104** in the cavity **124** of the cage **120**. In an exemplary embodiment, the spring slip **280** is received in the pocket **236**. The spring clip **280** engages the top **230** and presses against the top **230**. The guide ribs **237** may locate the spring clip **280** relative to the housing **220**. The spring clip **280** presses the cable connector module **104** toward the socket connector **122** to electrically connect the cable connector module **104** to the socket connector **122**.
(30) The spring clip **280** includes latches **282** at first and second sides **284**, **286** of the spring clip

280. The latches **282** are used to secure the sprint clip **280** to the cage **120**. The latches **282** may be coupled to the side walls **250**, **252**, such as to the openings **262**.
(31) The spring clip **280** includes at least one spring beam **290**, such as a pair of spring beams **290**. The spring beams **290** extend between the first side **284** and the second side **286** of the spring clip **290**. The spring beams **290** are connected by connecting beams **292**. The spring beams **290** are curved, such as being curved downward to engage the cable connector module **104**. The spring beams **290** are received in the pocket **236**, such as between the guide ribs **237**. Windows **294** are defined between the spring beams **290**. The windows **284** may receive corresponding guide ribs **237**.
(32) The socket connector **122** includes an array of interposer contacts **200** held together by a substrate **202**. The socket connector **122** may include a frame **204** holding the substrate **202**. The frame **204** may be rectangular. The frame **204** is configured to be coupled to the cage **120**. Additionally, or alternatively, the frame **204** may be coupled to the circuit board **110**. In an exemplary embodiment, the frame **204** includes an opening **206** that receives the substrate **202**. The substrate **202** may fill the opening **206**. The opening **206** may receive a portion of the cable connector module **104**, such as for mating with the interposer contacts **200**. The frame **204** includes frame members **208** defining the opening **206**. In the illustrated embodiment the frame **204** is rectangular having the frame members **208** arranged around the perimeter of the frame **204** (for example, in a rectangular configuration). The frame **204** is configured to be coupled to the cage **120** and/or the circuit board **110**.
(33) In various embodiments, the substrate **202** is a printed circuit board including the interposer contacts **200** coupled to the printed circuit board. The interposer contacts **200** may be defined by circuits, traces, vias, and the like of the printed circuit board. The interposer contacts **200** may be separate contacts soldered to the printed circuit board.
(34) In other embodiments, the substrate **202** is a film or plate and the interposer contacts **200** are separate contacts which may be held by or coupled to the film. The substrate **202** is manufactured from an insulative material, such as a polyimide material, to electrically isolate the interposer contacts **200** from one another.
(35) In an exemplary embodiment, the interposer contacts **200** are compressible contacts. In various embodiments, the interposer contacts **200** may be stamped and formed contacts, such as dual compression contacts having spring beams at both ends of the contacts and main bodies of the contacts between the spring beams held in the substrate **202**. The interposer contacts **200** may be LGA contacts.
(36) In various embodiments, the interposer contacts **200** are conductive polymer columns. The conductive polymer contacts may be conductive elastomeric connectors having conductive (metallic) particles embedded in an elastomeric material, such as a silicone rubber material. Each interposer contact **200** includes an upper mating interface and a lower mating interface. In various embodiments, the interposer contacts **200** are dual compressible contacts that are compressible at both the upper mating interface and the lower mating interface, such as for mating with the cable connector module **104** and the circuit board **110**, respectively. Optionally, the interposer contacts **200** may be arranged in groups, with each group including a pair of signal contacts surrounded by a ring or fence of ground contacts. The groups are arranged in rows and columns. Other arrangements are possible in alternative embodiments.
(37) FIG. **15** is a cross sectional view of the communication system **100** in accordance with an exemplary embodiment showing the electronic assembly **102** and the circuit board **110**. The cable connector module **104** is coupled to the socket connector **122**. The cable connector module **104** is pressed against the socket connector **122** by the spring clip **280** (FIG. **3**) to electrically connect the cable connector module **104** to the socket connector **122**. The cable connector module **104** is pressed downward to compress the interposer contacts **200** of the socket connector **122**. In an exemplary embodiment, the interposer contacts **200** are dual compression contacts that are

compressible at the upper interface (for example, with the cable connector module **104**) and at the lower interface (for example, with the circuit board **110**).
(38) Each interposer contact **200** includes an upper contact portion **210** and a lower contact portion **212**. The upper contact portion **210** is compressible. The upper contact portion **210** is configured to be coupled to the corresponding mating contact (not shown) at the bottom of the cable connector module **104**. The lower contact portion **212** is compressible. The lower contact portion **212** is configured to be terminated to the board contact (not shown) at the upper surface of the circuit board **110**. In the illustrated embodiment, the interposer contacts **200** are conductive polymer columns, such as conductive elastomeric connectors. The interposer contacts **200** are held by the substrate **202**. The upper contact portions **210** extend above the substrate **202** for connection to the cable connector module **104**. The lower contact portions **212** extend below the substrate **202** for connection to the circuit board **110**.
(39) FIG. **16** is a cross sectional view of the communication system **100** in accordance with an exemplary embodiment showing the electronic assembly **102** and the circuit board **110**. The cable connector module **104** is coupled to the socket connector **122**. The cable connector module **104** is pressed against the socket connector **122** by the spring clip **280** (FIG. **3**) to electrically connect the cable connector module **104** to the socket connector **122**. The cable connector module **104** is pressed downward to compress the interposer contacts **200** of the socket connector **122**. In an exemplary embodiment, the interposer contacts **200** are dual compression contacts that are compressible at the upper interface (for example, with the cable connector module **104**) and at the lower interface (for example, with the circuit board **110**).
(40) Each interposer contact **200** includes the upper contact portion **210** and the lower contact portion **212**. The upper and lower contact portions **210**, **212** are compressible. In the illustrated embodiment, the interposer contacts **200** are stamped and formed contacts. The interposer contacts **200** may be LGA contacts. The interposer contacts **200** include upper spring beams at the upper contact portions **210**. The interposer contacts **200** include lower spring beams at the lower contact portions **212**. The upper and lower spring beams compressible. Main bodies of the interposer contacts **200** are held by the substrate **202**. The interposer contacts **200** may include other shapes or features in alternative embodiments. The upper contact portions **210** extend above the substrate **202** for connection to the cable connector module **104**. The lower contact portions **212** extend below the substrate **202** for connection to the circuit board **110**.
(41) With reference back to FIG. **3**, and with additional reference to FIG. **4**, which is a bottom perspective view of the cable connector module **104**, the cable connector module **104** includes the cable assemblies **300** terminated to the circuit card **302**, such as being soldered to the circuit card **302**. The circuit card **302** includes mating pads **388** at a bottom of the circuit card **302**. The mating pads **388** are configured to be mated with corresponding interposer contacts **200** when the cable connector module **104** is plugged into the socket connector **122**. Optionally, the mating pads **388** may be arranged in groups, with each group including a pair of signal pads surrounded by a ring or fence of ground pads. The groups are arranged in rows and columns. Other arrangements are possible in alternative embodiments.
(42) Each cable assembly **300** includes a cable **310** and a support structure for the cable **310**. The support structure is used to couple an end of the cable **310** to the circuit card **302**. The cable connector module **104** may include a heat transfer element (not shown) thermally coupled to the cable assembly **300**, such as to dissipate heat from components on the circuit card **302**.
(43) In an exemplary embodiment, the cable connector module **104** includes a cable holder **304** that holds the cable assemblies **300** relative to the circuit card **302**. The cable connector module **104** includes a connector housing **306** having a cavity **308** that holds the cable assemblies **300** and the circuit card **302**. The connector housing **306** holds the circuit card **302** for mating with the socket assembly **108**. The connector housing **306** may be a metal shell or cage that receives the cable assembly **300**. The connector housing **306** is configured to be coupled to the socket connector **122**,

such as to the frame **204**, to position the mating interface of the circuit card **302** relative to the socket connector **122** for mating to the interposer contacts **200**. The cage **120** positions the connector housing **306**, and thus the circuit card **302**, in the cavity **124** for mating with the socket connector **122**.

(44) The cable holder **304** is coupled to the cables **310** and holds the cables **310** relative to each other within the cavity **308** of the connector housing **306**. The cable holder **304** may be coupled to the circuit card **302** to hold the cables **310** relative to the circuit card **302**. The cable holder **304** provides strain relief for the cables **310**. In alternative embodiments, the cable assembly **300** may be provided without the cable holder **304**. Rather, the cables **310** may be unsupported or freely arranged in the connector housing **306**. The circuit card **302** is coupled to the connector housing **306** to position the mating interface of the circuit card **302** for mating with the socket assembly **108**. The cable holder **304** is coupled to the connector housing **306** to position the cables **310** relative to the connector housing **306**.

(45) FIG. **5** is a top perspective view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. FIG. **5** shows a plurality of the cable assemblies **300** terminated to the circuit card **302**. The cable assemblies **300** are supported by the cable holder **304**. The connector housing **306** (shown in FIG. **3**) is removed to illustrate the cable assemblies **300** and the circuit card **302**.

(46) In the illustrated embodiment, the cable assemblies **300** are stacked in multiple rows, such as three or more rows. In various embodiments, the cable connector module **104** may include at least thirty-six (36) cable assemblies **300** terminated to the circuit card **302** in an area of approximately 30 mm by 20 mm. For example, the cable assemblies **300** may be arranged in a 4×9 matrix. However, the cable connector module **104** may include greater or fewer cable assemblies **300** in the termination area in alternative embodiments. The termination area may be larger or smaller in alternative embodiments, which may include greater or fewer cable assemblies **300** in alternative embodiments The cable assemblies **300** may be grouped together, such as in three or more groups (only one group is illustrated in FIG. **5**). Each group of cable assemblies **300** are terminated to a pad or section of the circuit card.

(47) The circuit card **302** includes an upper surface **380** and a lower surface **382** opposite the upper surface **380**. In an exemplary embodiment, the circuit card **302** includes contact pads **384** at the upper surface **380** configured to be electrically connected to the signal conductors of cables **310**. The contact pads **384** are circuits of the circuit card **302** and may be connected to plated vias extending through the circuit card **302** to the lower surface **382**. The contact pads **384** may be arranged in groups, such as pairs. In the illustrated embodiment, the contact pads **384** are all provided on the upper surface **380**. However, in alternative embodiments, the contact pads **384** may additionally be provided on the lower surface **382**. Optionally, the contact pads **384** may be arranged in a ground-signal-signal-ground arrangement. In the illustrated embodiment, the contact pads **384** are provided in multiple rows along the circuit card **302**. The rows are aligned parallel to the front and the rear of the circuit card **302**. The circuit card **302** is densely populated with the contact pads **384** to allow a large number of cables **310**, and thus a large number of signal lines, to be electrically connected to the circuit card **302**.

(48) In an exemplary embodiment, the circuit card **302** includes ground vias **386** at the upper surface **380**. The ground vias **386** are located proximate to the contact pads **384**. The ground vias **386** are electrically connected to the ground plane. The cable assemblies **300** are coupled to the corresponding ground vias **386**.

(49) The circuit card **302** includes mating pads **388** (shown in FIG. **4**) at the lower surface **382** configured to be electrically connected to corresponding interposer contacts **200** of the socket assembly **108** (both shown in FIG. **3**). The mating pads **388** are electrically connected to corresponding contact pads **384** through plated vias or other circuits of the circuit card **302**. In an exemplary embodiment, the mating pads **388** are all provided on the lower surface **382**. However,

the mating pads **388** may be provided on both the upper surface **380** and the lower surface **382** in alternative embodiments, such as when the circuit card **302** is a pluggable card configured to be plugged into a card slot of a receptacle connector.

(50) In an exemplary embodiment, each cable assembly **300** includes the cable **310**, a conductor support **312** coupled to the end of the cable **310**, and a ground structure **314** used to electrically connect the cable **310** to the circuit card **302**. In various embodiments, the ground structure **314** is a ground clip and may be referred to hereinafter as a ground clip **314**. The ground clip **314** is coupled to the end of the cable **310**. The ground clip **314** and the conductor support **312** support the cable **310** relative to the circuit card **302**. For example, the ground clip **314** and the conductor support **312** hold the cable **310** at an angle relative to the circuit card **302** to allow the cable **310** to lift off of and away from the circuit card **302**, rather than laying flat or parallel to the circuit card **302**. Such an arrangement allows tighter packaging of the cable assemblies **300**, such as to increase the density of the cable connector module **104** for a given footprint of the circuit card **302**. Other types of ground structures **314** may be used in alternative embodiments to electrically connect the cable **310** to the circuit card **302**, such as a bus bar, a crimp barrel, a ground cage, or ground hood, and the like. The ground structure **314** may be a stamped and formed structure.

(51) The ground clip **314** is used to mechanically and electrically connect the cable **310** to the circuit card **302**. In an exemplary embodiment, the ground clip **314** is a multi-piece structure. For example, the ground clip **314** may include multiple stamped and formed pieces that are stamped and formed separately from each other and then coupled together, such as being welded together to form the ground clip **314**. In the illustrated embodiment, the ground clip **314** includes a bottom ground rake **316** and a top ground hood **318**. Optionally, the top ground hood **318** of multiple cable assemblies **300**, such as the cable assemblies within each row, may be ganged or integrated together as a single top ground hood. However, in alternative embodiments, each cable assembly **300** may include a separate top ground hood **318**.

(52) In an exemplary embodiment, the ground clip **314** is used to direct the cable **310** away from the circuit card **302**, such as at a predetermined cable exit angle. For example, the ground clip **314** may hold the cable **310** at a cable exit angle that is non-parallel to the circuit card **302** and non-perpendicular to the circuit card **302**. In various embodiments, the ground clip **314** may hold the cable **310** at a cable exit angle of between 300 and 60°. Optionally, the ground clip **314** may hold the cable **310** at a cable exit angle of approximately 45°. The ground clip **314** holds the cable **310** at an angle to allow tight spacing of the cable assemblies **300**. For example, the contact pads on the circuit card **302** may be more densely populated (for example, closer spacing) by forcing the cable **310** to exit at an angle from the circuit card **302** as compared to conventional cable connector modules having the cables oriented generally parallel to the circuit card for termination to the circuit card.

(53) In an exemplary embodiment, the ground clip **314** is used to electrically connect to the cable **310**, such as to improve electrical performance of the cable connector module **104**. For example, the ground clip **314** may reduce excess insertion loss and cross talk due to tighter control of electromagnetic fields at the termination area. The ground clip **314** may electrically connect to the cable **310** at multiple locations. For example, the ground clip **314** may electrically connect at the top, the bottom and both sides to provide nearly circumferential connection between the cable **310** and the ground clip **314**. The ground clip **314** positions the cable **310** to have a short ground return path between the cable **310** and the circuit card **302** for improved electrical characteristics.

(54) Each cable **310** extends between the ground clip **314** and the cable holder **304**. The cables **310** transition between the ground clips **314** and the cable holder **304**. For example, the cables **310** lift off of the circuit card **302** immediately rearward of the termination area and extend rearward to the cable holder **304**. The cables **310** are stacked in rows in the cable holder **304**. In an exemplary embodiment, the cable holder **304** is coupled to the circuit card **302** to hold the cables **310** relative to the circuit card **302**. The cable holder **304** provides strain relief for the cables **310**. The cables

310 are exposed to air between the cable holder **304** and the ground clips **314**.

(55) The circuit card **302** is coupled to the connector housing **306** to position the mating interface of the circuit card **302** for mating with the socket assembly **108**. The cable holder **304** is coupled to the connector housing **306** to position the cables **310** relative to the connector housing **306**. In alternative embodiments, the cable assembly **300** may be provided without the cable holder **304**. Rather, the cables **310** may be unsupported or freely arranged in the connector housing **306**.

(56) In an exemplary embodiment, the cable holder **304** includes cable supports **390** arranged in a cable support stack **392**. The cable supports **390** hold the cables **310** at elevated positions above the circuit card **302**. For example, the cable supports **390** hold the cables **310** at different heights above the upper surface **380** of the circuit card **302**. In an exemplary embodiment, each cable support **390** extends between a top **391** and a bottom **393**. The cable supports **390** are stacked bottom-to-top on top of each other. The cable supports **390** may include locating features **395** for locating the cable supports **390** within the cable support stack **392**. For example, the locating features **395** may be posts and openings where the posts are received in openings to position and/or secure the cable supports **390** together. In alternative embodiments, the cable holder **304** may be a single piece structure that holds the cables **310** rather than multiple, stacked cable supports **390**.

(57) In an exemplary embodiment, the cable holder **304** includes cable channels **394** therethrough that receive corresponding cables **310**. The cable channels **394** are arranged in multiple rows. In the illustrated embodiment, the cable supports **390** include the cable channels **394** that receive corresponding cables **310**. The cable channels **394** may be open at the top **391** and the bottom **393** of each cable support **390** to receive corresponding cables **310** along both the top **391** and the bottom **393** of the cable support **390**. For example, the cable channels **394** include upper cable channels **394***a* at the top **391** and lower cable channels **394***b* at the bottom **393**. Optionally, the cables **310** may be sandwiched between the cable supports **390**. Alternatively, the cable channels **394** may be contained within the cable supports **390**, such as with each cable support **390** entirely circumferentially surrounding the corresponding cable channels **394**.

(58) In an exemplary embodiment, the cables **310** extend forward of the cable supports **390** to the ground clips **314**. The cables **310** may be preformed into a particular shape between the cable supports **390** and the ground clips **314**. For example, bends may be formed in the cables **310** at predetermined locations (lengths forward of the cable supports **390** and/or rearward from the ends of the cables **310**). The cables **310** may be shape-retaining to retain the pre-formed bend between the cable holder **304** and the ground clip **314**. Each row of cables **310** may have different shapes (for example, bends at different locations).

(59) In the illustrated embodiment, the cables **310** each have a horizontal portion immediately forward of the cable supports **390** and an angled portion between the horizontal portion and the ground clip **314**. In various embodiments, the angled portion is angled between approximately 150° and 120° relative to the horizontal portion. The angled portion may be angled at approximately 135° relative to the horizontal portion. In an exemplary embodiment, each cable **310** includes an end portion **311**, a bend portion **313** rearward of the end portion **311**, and a support portion **315** rearward of the bend portion **313**. The cable **310** is bent and non-linear in the bend portion **313**. The cable **310** is generally straight (linear) along the end portion **311** and the support portion **315**. The end portion **311** extends between the bend portion **313** and the ground clip **314** and the end of the cable **310**. The support portion **315** extends between the bend portion **313** and the cable holder **304**. The support portion **315** passes through the cable holder **304**. In an exemplary embodiment, the cables **310** are arranged in an inner row, an outer row, and at least one intermediate row. The cables **310** in the inner row are terminated to the circuit card **302** closest to the cable holder **304**. The cables **310** in the outer row are terminated to the circuit card **302** furthest from the cable holder **304**. The end portions **311** of the cables **310** in the inner row are shorter than the end portions **311** of the cables **310** in the outer row. The support portions **315** of the cables **310** in the inner row are shorter than the support portions **315** of the cables **310** in the outer row. The bend portions **313** of

the cables **310** in the inner row are located closer to the cable holder **304** than the bend portions **313** of the cables **310** in the outer row. The bend portions **313** of the cables **310** in the inner row are located at an elevation lower than the bend portions **313** of the cables **310** in the outer row.

(60) In various embodiments, the cables **310** may be surrounded by epoxy or hot melt forward of the cable supports **390** as a strain relief for the cables **310**. The cable supports **390** may form a dam to form the strain relief against. In other embodiments, the cables **310** may be in open air forward of the cable supports **390**, such as to improve signal integrity at the cable termination area compared to embodiments having epoxy or hot melt around the cables **310**. The cable supports **390** may form a dam to allow epoxy or hot melt to form around the cables **310** rearward of the cable supports **390**, such as to enhance the strain relief provided by the cable supports **390**.

(61) FIG. **6** is a perspective view of the cable **310** in accordance with an exemplary embodiment. The cable **310** includes at least one signal conductor and a shield structure providing electrical shielding for the at least one signal conductor. In an exemplary embodiment, the cables **310** are twin-axial cables. For example, each cable **310** includes a first signal conductor **320** and a second signal conductor **322**. The signal conductors **320**, **322** carry differential signals. The cable **310** includes an insulator **324** surrounding the signal conductors **320**, **322** and a cable shield **326** surrounding the insulator **324**. In various embodiments, the insulator **324** includes a single core surrounding both signal conductors **320**, **322**. In other various embodiments, the insulator **324** is a dual core insulator having a first dielectric element surrounding the first signal conductor **320** and a second dielectric element surrounding the second signal conductor **322**. The cable shield **326** provides circumferential shielding around the signal conductors **320**, **322**. The cable **310** includes a cable jacket **328** surrounding the cable shield **326**. In various embodiments, the cable **310** includes one or more drain wires **329** electrically connected to the cable shield **326**, such as a pair of drain wires **329** extending along opposite sides of the cable **310**, such as between the cable shield **326** and the cable jacket **328**. The drain wire(s) **329** are configured to be terminated to the circuit card **302**, such as being soldered to contact pads of the circuit card **302**. In an exemplary embodiment, the drain wires **329** are configured to be electrically connected to the ground clip **314** (shown in FIG. **5**).

(62) In an exemplary embodiment, at an end of the cable **310**, the cable jacket **328**, the cable shield **326**, and the insulator **324** may be removed (e.g., stripped) to expose portions of the signal conductors **320**, **322**. Exposed portions **321**, **323** of the signal conductors **320**, **322** extend forward from an end **325** of the insulator. The exposed portions **321**, **323** are configured to be mechanically and electrically coupled (e.g., soldered) to corresponding contact pads **384** on the circuit card **302** (shown in FIG. **5**). The exposed portions **321**, **323** may be bent, such as bent inward toward each other (distance between reduced for tighter coupling and smaller trace spacing) and/or may be bent to extend along the surface of the circuit card **302** to terminate to the contact pads **384**.

(63) FIG. **7** is a perspective view of the conductor support **312** in accordance with an exemplary embodiment. Optionally, multiple conductor supports **312** may be combined to form a unitary structure. For example, FIG. **7** illustrates the conductor support for three cables **310** as a unitary structure. It should be understood that a single conductor support **312** for a single cable **310** may be utilized in alternative embodiments. The conductor support **312** includes a dielectric body used to hold the exposed portions **321**, **323** of the signal conductors **320**, **322** (shown in FIG. **6**). The conductor support **312** electrically isolates the signal conductors **320**, **322** from each other and from the ground clip **314** (shown in FIG. **5**).

(64) The conductor support **312** includes conductor channels **330** that receive the signal conductors **320**, **322**. The conductor channels **330** extend between a front and a rear of the conductor support **312**. The conductor channels **330** position the signal conductors **320**, **322** relative to each other. The conductor channels **330** may pass straight through the conductor support **312** between the front and the rear. However, in alternative embodiments, the conductor channels **330** may be curved or angled to change relative positions of the signal conductors **320**, **322** between the front and the rear.

For example, the conductor channels **330** may be closer together at the front and further apart at the rear. The conductor channels **330** may be open at the top or at the bottom of the conductor support **312** to receive the signal conductors **320**, **322** through the top side or the bottom side of the conductor support **312**. Alternatively, the signal conductors **320**, **322** may be fed into the conductor channels **330** through the rear of the conductor support **312**.

(65) The conductor support **312** includes a rear wall **332** at the rear of the conductor support **312**. The rear wall **332** is configured to face the end **325** of the insulator **324** (shown in FIG. **6**). The rear wall **332** may abut against the insulator **324**. The conductor support **312** includes a nose cone **334** at a front portion **336** of the conductor support **312**. The nose cone **334** at the front portion **336** is configured to be received in the ground clip **314**. The conductor channels **330** pass through the front portion **336**. In an exemplary embodiment, side walls **338** of the conductor support **312** may be angled inward from the rear wall **332** to the nose cone **334**.

(66) In various embodiments, conductor supports **312** of multiple cable assemblies **300** may be molded together as a unitary structure. By molding the conductor supports **312** together, the spacing between the cable assemblies **300** may be controlled by the conductor supports **312**.

(67) FIG. **8** is a perspective view of the bottom ground rake **316** in accordance with an exemplary embodiment. Optionally, multiple bottom ground rakes **316** may be combined to form a unitary structure. For example, FIG. **8** illustrates the bottom ground rake for three cables **310** as a unitary structure. It should be understood that a single bottom ground rake **316** for a single cable **310** may be utilized in alternative embodiments. The bottom ground rake **316** is used as a mechanical and electrical connector between the cable **310** and the circuit card **302** (shown in FIG. **5**). The bottom ground rake **316** is manufactured from a conductive material, such as a metal material. In an exemplary embodiment, the bottom ground rake **316** is stamped and formed from a metal plate into a shape configured to mechanically and electrically connect the cable **310** to the circuit card **302**. The bottom ground rake **316** is configured to be electrically connected to the cable shield **326** of the cable **310**. The bottom ground rake **316** is configured to be electrically connected to the circuit card **302**.

(68) The bottom ground rake **316** includes a support wall **340** used to support the cable **310**. The bottom ground rake **316** includes a lower grounding tab **342** extending from the support wall **340**. The lower grounding tab **342** is configured to be electrically connected to the cable **310**, such as to a lower portion of the cable shield **326**. The lower grounding tab **342** includes a generally planar inner surface that faces the lower portion of the cable shield **326**. The lower grounding tab **342** has a large surface area for electrical connection with the cable shield **326**. In various embodiments, the inner surface of the lower grounding tab **342** may be directly coupled to the lower portion of the cable shield **326** to create a DC electrical connection with the cable shield **326**. In other embodiments, the inner surface of the lower grounding tab **342** may be spaced apart from, but located in close proximity to, the lower portion of the cable shield **326** to create a capacitive electrical connection between the lower grounding tab **342** and the cable shield **326**.

(69) The bottom ground rake **316** includes side connecting tines **344** configured to be electrically connected to the sides of the cable **310**. In various embodiments, the side connecting tines **344** may be directly connected to the cable shield **326** at the sides of the cable **310**, such as being soldered or compression coupled to the cable shield **326** at the sides of the cable **310**. Alternatively, the side connecting tines **344** may be located in close proximity to the sides of the cable shield **326** to create a capacitive electrical connection between the side connecting tines **344** and the cable shield **326**. However, in alternative embodiments, the side connecting tines **344** may be electrically connected to the sides of the cable **310** via the drain wires **329**. For example, the side connecting tines **344** may be drain wire tines and may be referred to hereinafter as drain wire tines **344**. The drain wire tines **344** extending from the support wall **340** for electrical connection to the drain wires **329** of the cable **310**. For example, the drain wire tines **344** may be provided at both sides of the support wall **340** to connect with both drain wires **329**. In an exemplary embodiment, drain wire slots **346**

are defined between pairs of the drain wire tines **344** that receive the drain wires **329**. The drain wire tines **344** may be connected to the drain wires **329** by an interference fit. Alternatively, the drain wire tines **344** may be soldered to the drain wires **329**. The drain wires **329** create direct electrical paths between the bottom ground rake **316** and the cable shield **326**. For example, the drain wires **329** are directly coupled to (DC electrical connection) the drain wire tines **344** and to the cable shield **326**.

(70) The bottom ground rake **316** includes one or more mounting tabs **348** extending from the support wall **340**. The mounting tabs **348** are used to mount the bottom ground rake **316** to the circuit card **302**. In the illustrated embodiment, the mounting tabs **348** are compliant pins, such as eye-of-the-needle pins, configured to be press fit into plated vias of the circuit card **302**. In alternative embodiments, the mounting tabs **348** may be solder tabs configured to be soldered to the circuit card **302**.

(71) In an exemplary embodiment, the support wall **340** includes a lower panel **350** and a support panel **352**. The lower panel **350** and the support panel **352** form a pocket that receives the conductor support **312** and the end of the cable **310**. The lower panel **350** defines a base of the support wall **340** that is configured to be mounted to the circuit card **302**. For example, the lower panel **350** is configured to rest on the upper surface of the circuit card **302**. The support panel **352** extends forward and upward at an angle from the lower panel **350**. The support panel **352** supports the front of the conductor support **312** and the end of the cable **310**. The lower panel **350** supports the bottom of the conductor support **312**.

(72) In an exemplary embodiment, the lower grounding tab **342** extends rearward and upward from the lower panel **350** at an angle, which may define the cable exit direction for the cable **310** from the bottom ground rake **316**. For example, the lower grounding tab **342** may be angled transverse (for example, non-parallel) to the lower panel **350** to extend along the cable **310**. In various embodiments, the lower grounding tab **342** may be angled at between 30° and 60° relative to the lower panel **350** (horizontal), such as approximately 45°. The mounting tabs **348** extend rearward from the lower panel **350** for connection to the circuit card **302**. The drain wire tines **344** extend forward from the lower panel **350** and/or the support panel **352**.

(73) In an exemplary embodiment, the support panel **352** is angled transverse (for example, non-parallel) relative to the lower panel **350**. For example, the support panel **352** may be angled at between 30° and 60° relative to the lower panel **350**, such as approximately 45°. The angles of the panels **350**, **352** control the cable exit angle from the bottom ground rake **316** and thus the circuit card **302**. For example, the plane defined by the support panel **352** defines the angle of the end **325** of the insulator **324** of the cable **310**. The cable **310** extends from the bottom ground rake **316** in a cable exit direction that is perpendicular to the plane of the support panel **352**.

(74) In an exemplary embodiment, the support panel **352** includes a window **354** therethrough. The window **354** is configured to receive the signal conductors **320**, **322**. The window **354** is configured to receive the nose cone **334** at the front portion **336** of the conductor support **312**. Optionally, the window **354** is open at a top of the support panel **352**. The drain wire tines **344** and the drain wire slots **346** are located on opposite sides of the support panel **352**.

(75) FIG. **9** is a perspective view of the top ground hood **318** in accordance with an exemplary embodiment. Optionally, multiple top ground hoods **318** may be combined to form a unitary structure. For example, FIG. **9** illustrates the top ground hood for three cables **310** as a unitary structure. It should be understood that a single top ground hood **318** for a single cable **310** may be utilized in alternative embodiments. The top ground hood **318** is used as a mechanical and electrical connector between the cable **310** and the circuit card **302** (shown in FIG. **5**). The top ground hood **318** is manufactured from a conductive material, such as a metal material. In an exemplary embodiment, the top ground hood **318** is stamped and formed from a metal plate into a shape configured to mechanically and electrically connect the cable **310** to the circuit card **302**. The top ground hood **318** is configured to be electrically connected to the cable shield **326** of the cable

310. The top ground hood **318** is configured to be electrically connected to the circuit card **302**.
(76) The top ground hood **318** includes a cover **360** used to shield the termination area of the cable **310** to the circuit card **302**. The cover **360** has an inner surface **362** that defines a shield pocket **364**. The exposed portions of the signal conductors extend into the shield pocket **364** for termination to the circuit card **302**. In an exemplary embodiment, the cover **360** includes an upper cover panel **366** above the shield pocket **364** and a front cover panel **368** forward of the shield pocket **364**.
(77) The top ground hood **318** includes an upper grounding tab **370** extending from the cover **360**. The upper grounding tab **370** is configured to be electrically connected to the cable **310**, such as to an upper portion of the cable shield **326**. The upper grounding tab **370** includes a generally planar inner surface that faces the upper portion of the cable shield **326**. The upper grounding tab **370** has a large surface area for electrical connection with the cable shield **326**. In various embodiments, the inner surface of the upper grounding tab **370** may be directly coupled to the upper portion of the cable shield **326** to create a DC electrical connection with the cable shield **326**. In other embodiments, the inner surface of the upper ground tab **370** may be spaced apart from, but located in close proximity to, the upper portion of the cable shield **326** to create a capacitive electrical connection between the upper grounding tab **370** and the cable shield **326**.
(78) In an exemplary embodiment, the upper grounding tab **370** extends rearward and upward from the upper cover panel **366** at an angle, which may define the cable exit direction for the cable **310** from the top ground hood **318**. For example, the upper grounding tab **370** may be angled transverse (for example, non-parallel) to the upper cover panel **366** (horizontal) to extend along the cable **310**. In various embodiments, the upper grounding tab **370** may be angled at between 30° and 60° relative to the upper cover panel **366**, such as approximately 45°.
(79) The top ground hood **318** includes one or more mounting tabs **372** extending from the cover **360**. The mounting tabs **372** are used to mount the top ground hood **318** to the circuit card **302**. In the illustrated embodiment, the mounting tabs **372** are compliant pins, such as eye-of-the-needle pins, configured to be press fit into plated vias of the circuit card **302**. In alternative embodiments, the mounting tabs **372** may be solder tabs configured to be soldered to the circuit card **302**. In the illustrated embodiment, the mounting tabs **372** extend from the bottom edge of the front cover panel **368** for connection to the circuit card **302**.
(80) In an exemplary embodiment, the top ground hood **318** including one or more connecting tabs **374** extending from the cover **360**. The connecting tabs **374** are used to mechanically and electrically connect the top ground hood **318** to the bottom ground rake **316**. In the illustrated embodiment, the connecting tabs **374** extend from the sides of the cover **360**. The connecting tabs **374** are configured to be soldered or welded to the bottom ground rake **316**, such as to the support wall **340** or drain wire tines **344**.
(81) FIG. **10** is a perspective view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. FIG. **10** shows the cable connector module **104** during an intermediate stage of assembly. During assembly, the cable assemblies **300** are coupled to the circuit card **302**. In various embodiments, the bottom ground rake **316** and/or the conductor support **312** may be coupled to the end of the cable **310** prior to coupling the bottom ground rake **316** and the conductor support **312** to the circuit card **302**. However, in alternative embodiments, the bottom ground rake **316** and the conductor support **312** may be coupled to the circuit card **302** prior to coupling the end of the cable **310** to the bottom ground rake **316** and the conductor support **312**.
(82) During assembly, the exposed portions **321**, **323** of the signal conductors **320**, **322** are coupled to the conductor support **312**. The signal conductors **320**, **322** are loaded into the conductor channels **330**. For example, the conductor channels **330** may be open at the top of the conductor support **312** such that the signal conductors **320**, **322** may be loaded into the conductor channels **330** from above. The rear wall **332** faces, and may abut against, the end **325** of the insulator **324**. In an exemplary embodiment, the cable **310** extends away from the conductor support **312** in a cable exit direction. The angle of the rear wall **332** (relative to the circuit card **302**) controls the cable exit

direction relative to the circuit card **302**. For example, the cable exit direction may be perpendicular to the rear wall **332**. The conductor support **312** may be used to support the drain wires **329**. The dielectric material of the conductor support **312** controls impedance along the signal paths. In various embodiments, the conductor support **312** is made of low loss material to decrease insertion loss along the signal paths.

(83) In various embodiments, the conductor support **312** may be coupled to the bottom ground rake **316** of the ground clip **314**. For example, the bottom ground rake **316** may position and support the conductor support **312** to position the conductor support **312** relative to the circuit card **302** to control the position and orientation of the cable **310** (for example, to control the cable exit direction). Optionally, the conductor support **312** may be pre-formed separate from the bottom ground rake **316**, such as being molded separate from the bottom ground rake **316**. The conductor support **312** is then coupled to the bottom ground rake **316**, such as being press-fit into the ground clip and held by an interference fit. The conductor support **312** may be secured to the bottom ground rake **316** using adhesive, fasteners, clips or other securing means.

(84) The signal conductors **320**, **322** may be loaded into the conductor support **312** prior to coupling to the bottom ground rake **316**. Alternatively, the signal conductors **320**, **322** may be loaded into the conductor support **312** after the conductor support **312** is coupled to the bottom ground rake **316**.

(85) In alternative embodiments, the conductor support **312** may be formed in place on the bottom ground rake **316** rather than being separately manufactured and then assembled with the bottom ground rake **316**. For example, the conductor support **312** may be overmolded over a portion of the bottom ground rake **316**. The conductor support **312** is molded to the bottom ground rake **316** to fix the position of the conductor support **312** relative to the bottom ground rake **316**.

(86) In various embodiments, the conductor support **312** of multiple cable assemblies **300** may be integrated as a unitary, monolithic structure. For example, the conductor supports **312** may be co-molded together, which controls spacing and relative positioning of the cables **310**. In various embodiments, the conductor supports **312** may be overmolded over the bottom ground rakes **316** to control relative positioning of the bottom ground rakes **316** of multiple cable assemblies **300**.

(87) When assembled, the exposed portions **321**, **323** of the conductors **320**, **322** extend forward of the conductor support **312**, such as for termination to the circuit card **302**. The drain wires **329** pass through the drain wire slots **346** forward of the bottom ground rake **316** for termination to the circuit card **302**. The drain wires **329** may be held in the drain wire slots **346** by an interference fit to electrically connect the drain wires **329** to the bottom ground rake **316**. Alternatively, the drain wires **329** may be soldered to the drain wire tines **344** to electrically connect the drain wires **329** to the bottom ground rake **316**. The drain wires **329** connect the bottom ground rake **316** to the cable shield **326**, such as to opposite sides (right side and left side) of the cable **310**.

(88) During assembly, the mounting tabs **348** of the bottom ground rake **316** are coupled to the circuit card **302**. For example, the mounting tabs **348** may be press-fit into the ground vias **386**. Alternatively, the mounting tabs **348** may be soldered to corresponding circuits of the circuit card **302**.

(89) During assembly, the exposed portions **321**, **323** of the signal conductors **320**, **322** are coupled to the corresponding contact pads **384** at the upper surface **380** of the circuit card **302**. For example, the signal conductors **320**, **322** are soldered to the contact pads **384**. Similarly, the ends of the drain wires **329** are coupled to the corresponding contact pads **384** of the circuit card **302**. For example, the drain wires **329** are soldered to the contact pads **384** to connect to a ground plane at the upper surface **380** of the circuit card **302**. The drain wires **329** extend along (for example, parallel to and spaced apart from) the exposed portions **321**, **323**. The drain wires **329** are located between the pairs of exposed portions **321**, **323** to provide shielding between the pairs of signal conductors **320**, **322**. The signal conductors **320**, **322** transition from the end of the insulator **324**, through the conductor support **312**, to the circuit card **302**. The exposed portions **321**, **323** of the signal

conductors **320**, **322** are bent at an angle relative to the cable axis to transition to the circuit card **302**.

(90) FIG. **11** is a top perspective view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. FIG. **12** is a rear perspective view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. FIGS. **11** and **12** show the top ground hood **318** coupled to the bottom ground rake **316** and the circuit card **302**. In an exemplary embodiment, the top ground hood **318** is assembled after the bottom ground rake **316** and the cables **310** are terminated to the circuit card **302**.

(91) During assembly, the mounting tabs **372** extending from the cover **360** are coupled to the circuit card **302**. For example, the mounting tabs **372** are press-fit into the ground vias **386**. Alternatively, the mounting tabs **372** may be soldered to corresponding circuits of the circuit card **302**.

(92) During assembly, the connecting tabs **374** extending from the cover **360** are coupled to the bottom ground rake **316**. For example, the connecting tabs **374** are soldered or welded to the bottom ground rake **316**, such as to the support wall **340**. The support wall **340** and/or the drain wire tines **344** support the rear end of the top ground hood **318**, such as to position the top ground hood **318** relative to the conductors **320**, **322**. In an exemplary embodiment, the connecting tabs **374** are connected to the drain wire tines **344**, such as being welded to the drain wire tines **344**.

(93) FIG. **13** is a side view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. The cable assemblies **300** are coupled to the circuit card **302**. The ground clip **314** is coupled to the circuit card **302**. The ground clip **314** defines the cable exit angle from the circuit card **302**. The ground clip **314** provides electrical shielding for the cable **310** at the termination zone between the cable **310** and the circuit card **302**. The ground clip **314** creates an electrical path between the circuit card **302** and the cable shield **326** of the cable **310**. For example, the ground clip includes multiple electrical interfaces with the cable shield **326**, such as at the upper portion, the lower portion, and both the right and left side portions of the cable shield **326**. The electrical interfaces between the ground clip **314** and the cable **310** may be made via solderless connections. For example, the upper and lower connections may be made by direct, interference fit connections or capacitive coupling between the ground clip **314** and the cable shield and the right and left side connections may be made by interference fit connections between the ground clip **314** and the drain wires **329**. The multiple connection points are provided around the cable shield **326**, such as on all four sides of the cable shield **326** to efficiently common the ground clip **314** and the cable shield **326** allowing efficient operation at high frequencies, such as between DC and 67 GHz. The ground structure allows efficient high-speed operation for the system, such as at 224 Gbps.

(94) The circuit card **302** extends between the upper surface **380** and the lower surface **382**. The contact pads **384** are provided at the upper surface **380**. The mating pads **388** are provided at the lower surface **382**. In an exemplary embodiment, the contact pads **384** include both signal contact pads **384*a*** (FIG. **11**) and ground contact pads **384*b*** (FIG. **11**). The ground contact pads **384*b*** may be discrete contact pads. In other various embodiments, the ground contact pads **384*b*** may be defined by a ground plane **383** at the upper surface **380**. The contact pads **384** are connected to corresponding mating pads **388** by plated vias **385**. The plated vias **385** extend through the circuit card **302** between the upper surface **380** and the lower surface **382**. The plated vias **385** may be signal vias **385*a*** and ground vias **385*b***. The signal vias **385*a*** electrically connect the signal contact pads **384*a*** and the signal mating pads **388*a***. The ground vias **385*b*** electrically connect the ground contact pads **384*b*** and the ground mating pads **388*b***. In an exemplary embodiment, the signal contact pads **384*a*** and the signal mating pads **388*a*** are arranged in pairs. The ground contact pads **384*b***, the ground mating pads **388*b***, and the ground vias **385*b*** surround the signal contact pads **384*a***, the signal mating pads **388*a***, and the signal vias **385*a***, such as forming a ring or fence around the signal pairs.

(95) In an exemplary embodiment, the contact pads **384** and the mating pads **388** are electrically

connected only by the plated vias **385**. For example, the contact pads **384** and the signal mating pads **388** are electrically connected without circuit traces routed on other layers of the circuit card **302**. In an exemplary embodiment, the contact pads **384** are vertically aligned with the corresponding mating pads **388**. The plated vias **385** pass vertically through the circuit card **302** along via axes **387**. The contact pads **384** and the signal mating pads **388** are coincident with the via axes **387**. The plated vias **385** are oriented perpendicular to the upper surface **380** and the lower surface **382**. The vias **385** have the shortest length between the contact pad **384** and the corresponding mating pad **388** for high speed signaling through the circuit card **302**. The plated vias **385** extend the entire height of the circuit card **302** from the upper surface **380** to the lower surface **382** to connect the contact pads **384** and the mating pads **388**.
(96) When assembled, the bottom ground rake **316** and the top ground hood **318** are coupled to the circuit card **302** and form a cable pocket **376** that extends along a cable exit axis **378**. The end of the cable **310** is received in the cable pocket **376**. The cable **310** extends away from the circuit card **302** in a cable exit direction along the cable exit axis **378**. The conductor support **312** is received in the cable pocket **376** and supports the end of the cable **310**. The cable pocket **376** is defined between inner surfaces of the lower grounding tab **342** and the upper grounding tab **370**. The inner surfaces may be planar surfaces oriented parallel to each other. The lower grounding tab **342** and the upper grounding tab **370** are spaced apart from each other to receive the cable **310** therebetween. The lower grounding tab **342** and the upper grounding tab **370** extend parallel to the cable exit axis **378**. The lower grounding tab **342** and the upper grounding tab **370** position the cable **310** and locate the cable **310** along the cable exit axis **378**. The lower grounding tab **342** supports the cable **310** from below. The upper grounding tab **370** supports the cable **310** from above.
(97) In various embodiments, the lower grounding tab **342** directly engages the cable shield **326** of the cable **310** to electrically connect (DC electrical connection) the bottom ground rake **316** to the cable shield **326**. Additionally, or alternatively, the lower grounding tab **342** is capacitively coupled to the lower portion of the cable shield **326**. For example, the lower grounding tab **342** is closely positioned relative to the cable shield **326** but does not physically contact the cable shield **326** (small separation distance). The lower grounding tab **342** may be positioned at most 50 microns apart from the cable shield **326** to create a strongly capacitively coupled connection between the lower grounding tab **342** and the lower portion of the cable shield **326**. The large surface area of the lower grounding tab **342** provides an efficient capacitive connection between the lower grounding tab **342** and the cable shield **326**. A ground return path is defined between the bottom ground rake **316** and the cable shield **326** through the DC electrical connection or the capacitive connection between the lower grounding tab **342** and the lower portion of the cable shield **326**.
(98) In various embodiments, the upper grounding tab **370** directly engages the cable shield **326** of the cable **310** to electrically connect (DC electrical connection) the top ground hood **318** to the cable shield **326**. Additionally, or alternatively, the upper grounding tab **370** is capacitively coupled to the upper portion of the cable shield **326**. For example, the upper grounding tab **370** is closely positioned relative to the cable shield **326** but does not physically contact the cable shield **326** (small separation distance). The upper grounding tab **370** may be positioned at most 50 microns apart from the cable shield **326** to create a strongly capacitively coupled connection between the upper grounding tab **370** and the upper portion of the cable shield **326**. The large surface area of the upper grounding tab **370** provides an efficient capacitive connection between the upper grounding tab **370** and the cable shield **326**. A ground return path is defined between the top ground hood **318** and the cable shield **326** through the DC electrical connection or the capacitive connection between the upper grounding tab **370** and the upper portion of the cable shield **326**.
(99) In an exemplary embodiment, the lower grounding tab **342** and the upper grounding tab **370** are angled transverse relative to the circuit card **302**. For example, the lower grounding tab **342** and the upper grounding tab **370** may be angled between 30° and 60° relative to the (horizontal) circuit

card **302**. Optionally, the lower grounding tab **342** and the upper grounding tab **370** may be angled at approximately 45°. The lower grounding tab **342** and the upper grounding tab **370** define the cable exit angle at between 30° and 60° relative to the (horizontal) circuit card **302**, such as at approximately 45° to immediately lift the cable **310** off of the circuit card **302** and allow tight spacing of the cable assemblies **300** as compared to conventional cable connector modules having the cables oriented generally parallel to the circuit card for termination to the circuit card.
(100) The ground clip **314** is used to mechanically and electrically connect the cable **310** to the circuit card **302**. The mounting tabs **348** mechanically secure the ground clip **314** to the circuit card **302** holding the bottom ground rake **316** along the upper surface **380** of the circuit card **302**. In an exemplary embodiment, the ground clip **314** is used to direct the cable **310** away from the circuit card **302** at a predetermined cable exit angle. For example, the ground clip **314** may hold the cable **310** at a cable exit angle that is non-parallel to the circuit card **302** and non-perpendicular to the circuit card **302**. In various embodiments, the ground clip **314** may hold the cable **310** at a cable exit angle of between 30° and 60°. Optionally, the ground clip **314** may hold the cable **310** at a cable exit angle of approximately 45°. The ground clip **314** directs the cable **310** away from the upper surface **380** at an angle to allow tight spacing of the cable assemblies **300**. For example, the contact pads **384** on the circuit card **302** may be more densely populated (for example, closer spacing) by forcing the cable **310** to exit at an angle from the upper surface **380** of the circuit card **302** as compared to conventional cable connector modules having the cables oriented generally parallel to the circuit card for termination to the circuit card.
(101) In an exemplary embodiment, the ground clip **314** is used to electrically connect to the cable **310**, such as to improve electrical performance of the cable connector module **104**. For example, the ground clip **314** may reduce excess insertion loss and cross talk due to tighter control of electromagnetic fields at the termination area. The ground clip **314** positions the cable **310** to have a short ground return path between the cable **310** and the circuit card **302** for improved electrical characteristics. For example, the ground return path is defined from the cable shield **326** directly into the ground clip **314** through the drain wires **329** and the drain wire tines **344**, and directly from the ground clip **314** to the circuit card **302** through the mounting tabs **348**. The drain wire tines **344** may be soldered to the drain wires **329**. The drain wire tines **344** and the drain wires **329** provide multiple points of contact with the cable shield **326** at different sides of the cable **310** to reduce insertion loss and crosstalk by controlling electromagnetic fields around the end of the cable **310**. The exposed portions **321**, **323** of the signal conductors **320**, **322** have a short distance from the end **325** of the insulator **324** (shown in FIG. **6**) to the contact pads **384**. The conductor support **312** tightly controls the impedance in the termination area (between the end **325** of the insulator **324** and the contact pads **384**). The ground clip **314** provides shielding in the termination area. For example, the ground clip **314** occupies much of the surrounding space between the end **325** of the insulator **324** and the upper surface **380** of the circuit card **302** to reduce insertion loss and crosstalk by tightly controlling the electromagnetic fields in the termination area.
(102) FIG. **14** is a top perspective view of a portion of the cable connector module **104** in accordance with an exemplary embodiment. FIG. **14** shows the top ground hood **318** coupled to the bottom ground rake **316** and the circuit card **302**. In an exemplary embodiment, the top ground hood **318** includes a cable connector **371** configured to be coupled to the cable **310**. The cable connector **371** presses the drain wires **329** toward the cable shield **326**.
(103) The cable connector **371** extends from the upper grounding tab **370** and wraps at least partially around the end of the cable **310**. In an exemplary embodiment, the cable connector **371** includes connecting fingers **373**, **375** at opposite sides of the cable connector **371**. The connecting fingers **373**, **375** may extend from opposite sides of the upper grounding tab **370**. The connecting fingers **373**, **375** may be provided at or near the distal end of the upper grounding tab **370**.
(104) In an exemplary embodiment, the connecting fingers **373**, **375** may be folded or crimped around the sides of the cable **310**. The connecting fingers **373**, **375** are configured to be coupled to

the drain wires **329** at the sides of the cable **310**. The connecting fingers **373**, **375** may directly engage the exposed portions of the drain wires **329** to electrically connect to the drain wires **329**. Optionally, the connecting fingers **373**, **375** may directly engage the cable shield **326** to electrically connect to the cable shield **326**. The connecting fingers **373**, **375** are used to pinch the drain wires **329** inward, such as to hold the drain wires **329** against the cable shield **326**. In an exemplary embodiment, the connecting fingers **373**, **375** are crimped around the end of the cable **310** to press the drain wires **329** inward toward the cable shield **326**. In an exemplary embodiment, the connecting finger **373**, **375** extend a majority of a perimeter of the cable **310** between the upper grounding tab **370** and the lower grounding tab **342**. The connecting fingers **373**, **375** may engage the lower grounding tab **342**. The connecting fingers **373**, **375** may press the lower grounding tab **342** inward toward the cable shield **326**.

(105) In an exemplary embodiment, the connecting fingers **373**, **375** may be located proximate to the end of the cable shield **326** to connect the drain wires **329** to the cable shield **326** proximate to the end of the cable shield **326**. The connecting fingers **373**, **375** prevent lift-off or separation of the drain wires **329** from the cable shield **326**, such as to create an improved ground return path from the cable shield **326** to the drain wires **329**.

(106) In an exemplary embodiment, the cable connector **371** is integral with the top ground hood **318**. For example, the cable connector **371** is stamped and formed with the top ground hood **318** from a common metal sheet. However, in alternative embodiments, the cable connector **371** is separate and discrete from the top ground hood **318**. For example, the cable connector **371** may be separately stamped and formed. The cable connector **371** may be coupled to the top ground hood **318**, such as to the upper grounding tab **370** and/or the lower grounding tab **342**. The cable connector **371** may be soldered or welded to the upper grounding tab **370**. In alternative embodiments, the cable connector **371** may be crimped onto the upper grounding tab **370**. In various embodiments, the cable connector may be a band wrapped entirely circumferentially around the cable **310** and the grounding tabs **370**, **342** to compress the drain wires **329** and the grounding tabs **370**, **342** inward toward the cable shield **326**, such as to press the drain wires **329** and the grounding tabs **370**, **342** into direct contact with the cable shield **326** to create multiple grounding points with the cable shield **326**. It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from its scope. Dimensions, types of materials, orientations of the various components, and the number and positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. § 112(f), unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function void of further structure.

Claims

1. An electronic assembly comprising: a socket assembly including a cage configured to be mounted to a circuit board, the cage having a cavity, the socket assembly including a socket connector received in the cavity of the cage, the socket connector including a substrate holding interposer contacts, each interposer contact including an upper contact portion and a lower contact portion, the upper contact portion being compressible, the lower contact portion being compressible, the lower contact portion being terminated to a board contact of the circuit board; and a cable connector module received in the cavity of the cage and coupled to the socket connector, the cable connector module including a housing having a cavity, the housing being coupled to the cage, the cable connector module including a circuit card held by the housing, the circuit card having signal contact pads at an upper surface of the circuit card and mating contact pads at a lower surface of the circuit card, the mating contact pads being coupled to the upper contact portions of corresponding interposer contacts, the cable connector module including cable assemblies coupled to the circuit card, each cable assembly including a cable, the cable having an insulator holding a first signal conductor and a second signal conductor, the cable having a cable shield surrounding the insulator, the first and second signal conductors having exposed portions extending forward of an end of the insulator at an end of the cable electrically connected to corresponding signal contact pads.
2. The cable assembly of claim 1, wherein the cage includes a top opening at the top of the cage, the cable connector module being top loaded into the cavity of the cage through the top opening, the mating contact pads being coupled to the upper contact portions from above.
3. The cable assembly of claim 1, wherein the interposer contacts are compressed by the cable connector module.
4. The cable assembly of claim 1, wherein the interposer contacts are dual compression contacts, wherein both the upper contact portions and the lower contact portions are compressed by the cable connector module.
5. The cable assembly of claim 1, further comprising a spring clip coupled to the cage, the spring clip engaging the housing of the cable connector module to hold the cable connector module in the cavity of the cage, the spring clip pressing the cable connector module toward the socket connector.
6. The cable assembly of claim 5, wherein the housing extends between a top and a bottom, the circuit card located at the bottom, the spring clip engaging the top to press downward against the top.
7. The cable assembly of claim 6, wherein the upper wall includes a pocket, the spring clip being received within the pocket.
8. The cable assembly of claim 5, wherein the cage includes a first side wall, a second side wall opposite the first side wall, and an end wall between the first side wall and the second side wall, the cable connector module located between the first side wall and the second side wall, the spring clip being coupled to the first side wall and the second side wall above the cable connector module.
9. The cable assembly of claim 5, wherein the spring clip includes a spring beam extending between a first side and a second side of the spring clip, the first and second sides being coupled to the cage, the spring beam being curved between the first and second sides to engage the cable connector module.
10. The cable assembly of claim 5, wherein the spring clip includes latching features latchably coupled to the cage.
11. The cable assembly of claim 1, wherein the cage includes a latching element, the housing including a latching element interfacing with the latching element of the cage to secure the housing in the cavity of the cage.
12. The cable assembly of claim 1, wherein the cage includes a mounting tab, the mounting tab being coupled to the circuit board to fix the cage relative to the circuit board.
13. The cable assembly of claim 1, wherein the cage includes a window, the cables passing through

the window.
14. The cable assembly of claim 1, wherein each cable assembly includes a ground clip coupled to the end of the cable, the ground clip being electrically connected to the cable shield to electrically connect the cable shield to the circuit board, the ground clip supporting the cable such that the cable extends from the circuit board in a cable exit direction angled transverse relative to a mounting surface of the circuit card.
15. The cable assembly of claim 14, wherein the ground clip supports the cable at the cable exit direction of between 300 and 60° relative to the mounting surface of the circuit card.
16. An electronic assembly comprising: a socket assembly including a cage configured to be mounted to a circuit board, the cage having walls extending between a top and a bottom of the cage, the walls defining a cavity, the socket assembly including a socket connector received in the cavity at the bottom of the cage, the socket connector configured to be mounted to the circuit board, the socket connector including a substrate holding interposer contacts, each interposer contact including an upper contact portion and a lower contact portion, the lower contact portion being terminated to a board contact of the circuit board; a cable connector module received in the cavity of the cage and coupled to the socket connector, the cable connector module including a housing having a cavity, the cable connector module including a circuit card held by the housing, the circuit card having signal contact pads at an upper surface of the circuit card and mating contact pads at a lower surface of the circuit card, the mating contact pads being coupled to the upper contact portions of corresponding interposer contacts, the cable connector module including cable assemblies coupled to the circuit card; and a spring clip coupled to the walls of the cage, the spring clip engaging the cable connector module to hold the cable connector module in the cavity of the cage, the spring clip pressing the cable connector module into the socket connector to mate the mating contact pads with the upper contact portions of the interposer contacts.
17. The cable assembly of claim 16, wherein the cage includes a top opening at the top of the cage, the cable connector module being top loaded into the cavity of the cage through the top opening, the mating contact pads being coupled to the upper contact portions from above.
18. The cable assembly of claim 16, wherein the interposer contacts are dual compression contacts, wherein both the upper contact portions and the lower contact portions are compressed by the cable connector module.
19. The cable assembly of claim 16, wherein the housing extends between a top and a bottom, the circuit card located at the bottom, the top including an upper wall, the spring clip engaging the upper wall to press downward against the upper wall.
20. The cable assembly of claim 16, wherein the spring clip includes a spring beam extending between a first side and a second side of the spring clip, the first and second sides being coupled to the cage, the spring beam being curved between the first and second sides to engage the cable connector module.
21. The cable assembly of claim 16, wherein each cable assembly including a cable and a ground clip coupled to an end of the cable, the ground clip coupling the cable to the circuit card, the cable having an insulator holding a first signal conductor and a second signal conductor, the cable having a cable shield surrounding the insulator, the first and second signal conductors having exposed portions extending forward of an end of the insulator at an end of the cable soldered to corresponding signal contact pads, the ground clip being electrically connected to the cable shield to electrically connect the cable shield to the circuit card.