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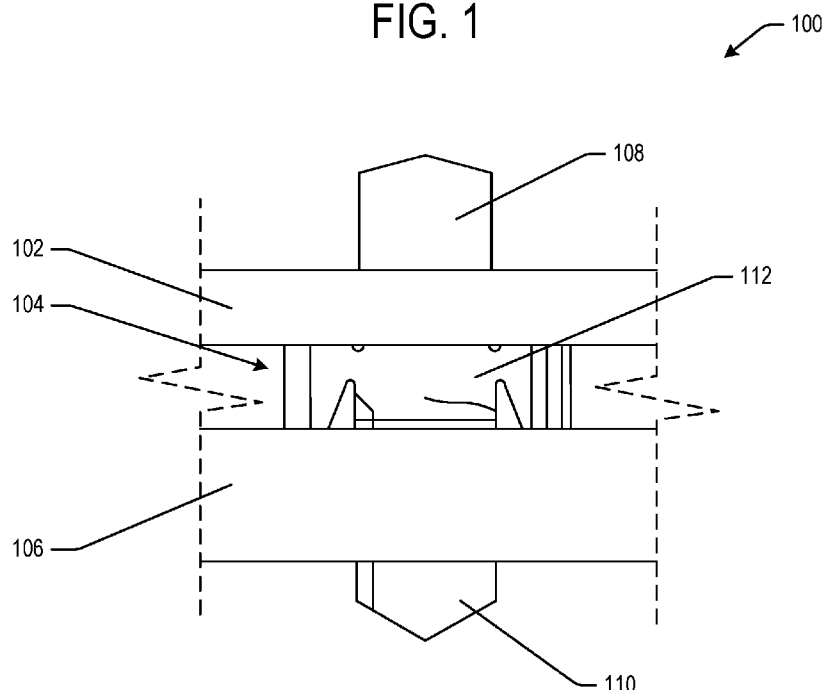
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- (54) Title: SHUNT CONTACT

FIG. 1



- (57) Abstract: An electrical assembly includes a circuit board, a resistive shunt, and a shunt contact configured for coupling to the circuit board and the resistive shunt. The shunt contact includes a board contacting portion, a shunt contacting portion, and a standoff portion spacing the board contacting portion from the shunt contacting portion. In examples, the shunt contacting portion includes one or more elastic fins that facilitate press fitting of the shunt contacting portion into a sensing opening in the shunt.



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SHUNT CONTACT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority of United States Provisional Patent Application No. 63/514,476, filed July 19, 2023, and titled “Press-Fit Electrical Sensing Contacts for Resistive Shunt,” the entire contents of which are hereby incorporated by reference.

FIELD OF THE TECHNOLOGY

[0002] The subject disclosure relates to electrical devices, and more particularly to electrical contacts that facilitate use of a resistive shunt with an electrical system.

BACKGROUND OF TECHNOLOGY

[0003] Many electrical applications, such as vehicles that are powered by batteries (electric vehicles, hybrid-electric vehicles, etc.) and the means for charging these batteries, require precise usage (e.g., current, voltage) measurements, to ensure normal operation and/or to meter energy usage. In addition, the magnitudes of the electrical currents involved in driving and charging operations for such applications are high, and special measures have to be applied in order to be able to withstand and/or accurately measure such high currents without overheating and with guaranteed accuracy and safety.

[0004] Various conventional methods are available for current measurement, including but not limited to, resistive shunts that develop a voltage drop that depends on the current. Many conventional resistive shunt schemes may be one or more of costly, difficult to install or use, and/or unreliable. Accordingly, there is a need in the art for improved electrical components and methods of making such components to improve resistive shunts in electrical applications.

SUMMARY OF THE TECHNOLOGY

[0005] The subject technology relates to improved electrical devices and methods of making those devices. In examples, aspects of this disclosure relate to improved shunt contacts that are used in connection with a resistive shunt, e.g., via which current through an electrical system may be measured. In examples, a shunt contact according to this disclosure can include a board contacting portion configured for securing to an electrical board, such as a printed circuit board, and a shunt contacting portion configured for securing to a shunt. A standoff portion may extend between the board contacting portion and the shunt contacting portion. In operation, the standoff portion may maintain a predetermined distance between the electrical board and the shunt. For example, the shunt contacts according to this disclosure may be less expensive, easier to install, and/or more reliable than some existing devices and components. Additional aspects of this disclosure relate to methods of making improved shunt contacts and measuring devices and assemblies including such shunt contacts.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] So that those having ordinary skill in the art to which the disclosed systems and techniques pertain will more readily understand how to make and use the same, reference may be had to the following drawings.

[0007] FIG. 1 is a partial front, plan view of an electrical assembly including a printed circuit board, a shunt contact, and a shunt, in accordance with aspects of this disclosure.

[0008] FIGS. 2A, 2B, and 2C are front, side, and bottom views, respectively, of the shunt contact of FIG. 1, in accordance with aspects of this disclosure.

[0009] FIGS. 3A and 3B are perspective and top views, respectively, of the shunt contact and a portion of the printed circuit of FIG. 1, in accordance with aspects of this disclosure.

[0010] FIGS. 4A and 4B are perspective and bottom views, respectively, of the shunt contact and a portion of the shunt of FIG. 1, in accordance with aspects of this disclosure.

[0011] FIGS. 5A and 5B are alternative configurations of a portion of a shunt contact, like the shunt contact of FIG. 1, in accordance with additional aspects of this disclosure.

[0012] FIG. 6 is a perspective view of an example shunt, such as the shunt shown in FIG. 1, in accordance with aspects of this disclosure.

[0013] FIG. 7A is a partial bottom view of the example shunt of FIG. 6 demonstrating current flow through the example shunt, in accordance with aspects of this disclosure.

[0014] FIG. 7B is the partial bottom view of FIG. 7A with a shunt contact disposed in a hole of the example shunt, in accordance with aspects of this disclosure.

[0015] FIG. 8 is an example electrical schematic showing concepts associated with the electrical assembly of FIG. 1, according to aspects of this disclosure.

[0016] FIG. 9 is a top view of a portion of a printed circuit, in accordance with aspects of this disclosure.

DETAILED DESCRIPTION

[0017] The subject technology may overcome prior art problems associated with some electrical components. In brief summary, the subject technology provides improved electrical components including shunt connectors for use in electrical devices. Without limitation, the

components and techniques described herein may provide shunt connectors that are cheaper to manufacture, more reliable, and/or simpler to use than similar conventional devices. Also in examples, the devices and techniques described herein may provide improved electrical connections when compared to similar conventional devices.

[0018] As noted above, conventional methods of measuring current in high current applications can include resistive shunts that develop a voltage drop related to the current through the electrical system. Conventional shunts suffer from drawbacks associated with one or more of complex manufacturing, unreliable sensing, e.g., over time and/or after thermal loads, unreliable electrical connections, and/or the like. For example, and without limitation, some conventional shunt arrangements require that posts, pins, or the like be fixed to a shunt, and that a circuit board associated with a measuring device then be fit, e.g., press-fit, on to the posts, pins, or the like. However, conventional press-fitting in this manner is often difficult because the pins do not line up with holes on the board, the metallization layer on the holes of the board is damaged or destroyed during the pressing operation, and/or other assembly difficulties.

[0019] Aspects of this disclosure may remedy some or all of these shortcomings of these and/or other conventional shunt assemblies and devices. For example, aspects of this disclosure may provide an improved shunt contact that facilitates ready coupling of a circuit board (e.g., associated with a measuring device or measuring circuit) to a shunt. Aspects of this disclosure also relate to an assembly including the shunt contact, the circuit board, and the shunt. Still further aspects of this disclosure relate to improved shunts that may facilitate both resistive shunt current measurement, but also magnetic current measurement, e.g., via a hall-effect sensor and systems including such shunts.

[0020] However, this disclosure is not limited to improvements of these shortcomings, and not all implementations of the systems and techniques described herein may result in such improvements. Moreover, while aspects of this disclosure may be particularly useful in electrical systems such as those found in electric vehicles or hybrid electric vehicles, the systems and techniques described herein may be useful in other electrical applications in which measuring a current through the system is desirable.

[0021] Aspects of the disclosure will now be explained in more detail with reference to the Figures.

[0022] FIG. 1 is a partial front elevation view of an electrical assembly 100. The electrical assembly 100 generally includes a circuit board 102, a shunt contact 104, and a shunt 106 (or shunt resistor). As detailed further herein, the shunt contact 104 electrically couples the circuit board 102 to the shunt 106. As is conventionally known, a shunt arrangement or resistive shunt arrangement facilitates current measurement through an electrical system, especially a high voltage and/or current electrical system, such as through the circuit board 102.

[0023] In examples, the circuit board 102 may be a printed circuit board, e.g., associated with a measuring device that may be used in an electrical system, such as in a battery management system. The circuit board 102 may comprise any conventional construction or material(s), including but not limited to material that is constructed from multiple layers of glass fibers impregnated with high temperature epoxy resin glue (such as FR4 material). In examples, and as detailed further herein, the circuit board 102 may include a number of conductive through holes, e.g., plated through holes, via which an electrical connection may be made to the board.

[0024] The shunt 106 may be a shunt resistor. In examples, the shunt 106 may be of a type that is conventionally known in the art. FIG. 6, detailed below, also provides an example shunt that may be used as the shunt 106 in some examples of this disclosure. Generally, the shunt 106 may be a resistor that is placed in series with an electrical circuit, such as a high current electrical circuit. The shunt 106 may be coupled to a measure device associated with (or embodied by) the circuit board 102, e.g., via a plurality of instances of the shunt contact 104. The shunt 106 may comprises a low ohm resistor, e.g., formed as a strip of low-resistance metal. In examples, the shunt 106 may be made from copper, a copper alloy (such as Manganin®), and/or or other conductive materials. As is conventionally known, a voltage drop across the shunt 106 may be measured and used to determine a current in the measured electrical circuit, e.g., by electronics on or associated with the circuit board 102.

[0025] The shunt contact 104 is a metallic member that facilitates connection of the shunt 106 to an electrical circuit (e.g., a measuring circuit) on the circuit board 102. As detailed further herein, the shunt contact 104 has a first portion 108 (also referred to herein as a board contacting portion 108) that is coupled to the circuit board 102 and a second portion 110 (also referred to herein as a shunt contacting portion 110) that is coupled to the shunt 106. A third, intermediate portion 112 (also referred to herein as a standoff portion 112) extends between the first portion 108 and the second portion 110. As illustrated in FIG. 1, the third portion 112 extends between and contacts the circuit board 102 and the shunt 106. In examples, the shunt contact 104 may be made of a single piece of conductive material, such as a single piece of metal, including but not limited to copper, copper alloy, and/or the like.

[0026] The shunt contact 104 is shown in more detail in FIGS. 2A, 2B, and 2C. More specifically, FIG. 2A is a front elevation view of the shunt contact 104, FIG. 2B is a side elevation

view of the shunt contact 104, and FIG. 2C is a bottom plan view of the shunt contact 104. In the views, the same reference numerals introduced in FIG. 1 are used to show the same features.

[0027] As illustrated in FIGS. 2A-2C, the shunt contact 104 includes the board contacting portion 108, the shunt contacting portion 110, and the standoff portion 112.

[0028] The board contacting portion 108 generally comprises a blade 202 made of a thin metallic material. The blade 202 is defined by a width between a first lateral side 204 and a second lateral side 206 (shown in FIG. 2A) and a thickness, t_l , between a first, front surface 208 and a second, rear surface 210 (shown in FIG. 2B). The blade 202 may be a lead or tail that is configured for insertion into a hole, e.g., a slotted hole, in a circuit board, such as the circuit board 102 shown in FIG. 1. Although illustrated as the blade 202, in other examples the board contacting portion 108 may be otherwise configured. For example, the board contacting portion 108 may be embodied as a pin, or any other shape suitable for creating a connection with the circuit board 102. Although the first lateral side 204 and the second lateral side 206 are illustrated as being substantially parallel to each other, in other examples the lateral sides 204, 206 may be angled relative to each other.

[0029] As also illustrated in FIG. 2A, a distal end 212 of the board contacting portion 108 includes a taper, e.g., generally comprising two surfaces sloped relative to each other. In examples, the taper may facilitate ready insertion of the distal end 212 of the board contacting portion 108 into a corresponding slot in the circuit board. In other examples, the distal end 212 may be otherwise configured, including but not limited to being a substantially linear edge, which may be perpendicular to or angled relative to one or both of the lateral sides 204, 206.

[0030] As best illustrated in FIG. 2A, the standoff portion 112 of the shunt contact 104 comprises two laterally extending members or flaps 214. Each of the flaps 214 extends laterally, e.g., from a longitudinal axis 216, to a lateral side 218. The lateral sides 218 are disposed, respectively, farther from the longitudinal axis 216 than the lateral sides 204, 206 of the board contacting portion 108. Accordingly, when the board contacting portion 108 is inserted into a corresponding hole in a circuit board, the flaps 214 create a footprint larger than the hole, to prevent insertion of the standoff portion 112 into the hole. As detailed further below, the lateral sides 218 of the flaps 214 also extend laterally beyond the lateral extents of the shunt contacting portion 110.

[0031] As shown in FIG. 2A, the flaps 214 extend longitudinally from a first edge 220 (an upper edge in the orientation of FIG. 2A) to a second edge 222 (a lower edge in the orientation of FIG. 2A). The first edge 220 and the second edge 222 are generally parallel to each other and define a standoff distance, d (shown in FIG. 2B). Using FIG. 1 for context, in the electrical assembly 100, the first edge 220 of each of the flaps 214 contacts a side (e.g. an underside in FIG. 1) of the circuit board 102, and the second edge 222 of each of the flaps 214 contacts a side (e.g., an upper side) of the shunt 106. The distance between the contacted sides of the circuit board 102 and the shunt 106 is defined by the standoff distance, d .

[0032] As illustrated best in FIG. 2C, each of the flaps 214 can optionally include one or more bends 224. In the illustrated example, the bends 224 cause a distal portion 226 of the flaps 214, e.g., proximate the lateral sides 218, to be angled relative to a central portion 228, e.g., a portion relatively closer to the longitudinal axis 216. In examples, the bends 224 in the flaps 214 may provide increased stiffness and or strength. For instance, the bends 224 may help to insure that the flaps 214 do not collapse, such as by folding along the longitudinal axis 216, when a strong force is applied such as during the insertion of the shunt contact 104 into the shunt 106, as detailed

further herein. Also in examples, the bends 224 may provide for other than a straight line of contact of the flaps 214 with the circuit board 102 and/or the shunt 106. That is, the flaps 214 may provide for increased stability of the circuit board 102 and/or the shunt 106. In still further examples, each of the flaps 214 may include more than one bend and/or the bend 224 may be formed at a different angle than that illustrated. As noted above, the bends 224 may be optional.

[0033] The shunt contacting portion 110 is configured for insertion into a sensing opening in a shunt, such as in the shunt 106 shown in FIG. 1. As illustrated best in FIG. 2C, the shunt contacting portion 110 includes two fins 230. The fins 230 generally comprise arcuate members configured to make an electrical connection within a sensing hole in the shunt. More specifically, each of the fins 230 includes an outer arcuate surface 232, at least a portion of which contacts an inner surface of the sensing hole, as described further herein. In the illustrated example, the fins 230 are arranged generally in an “S”-shaped cross-section.

[0034] The fins 230 have a thickness, t_2 , which may be sufficiently thin to allow for some relative movement of the fins 230. Specifically, an applied force acting laterally on the arcuate surfaces 232 of the fins 230 will cause the fins 230 to move elastically, e.g., to rotate about the longitudinal axis 216. This rotation or movement of the fins 230 causes the arcuate surfaces 232 of the fins 230 to move relatively closer to the longitudinal axis 216, e.g., to compress.

[0035] In examples, the fins 230 are elastic, such that the arcuate surfaces 232 are normally biased to the illustrated position. Accordingly, the fins 230 will be forced or biased against the applied force just described. As detailed further herein, this internal biasing force of the fins 230 will retain the shunt contact 104 in a sensing hole of the shunt. Stated differently, the soft bends of the fins 230 allow large fully-elastic motion at the lateral sides of the profile, assuring that

pressure is applied between the shunt contact 104 and an inner wall of the sensing hole, irrespective of the thermally-induced changes in the dimensions of the shunt contact 104 and/or of the sensing hole in the shunt. This large range of elastic motion may also allow for insertion into holes that have some positional misalignment.

[0036] As also illustrated in FIG. 2A, a distal end 234 of the shunt contact 104 may be angled, e.g., relative to outer sides of the fins 230. For example, the distal end 234 is illustrated as including a pair of tapered surfaces that come to a point proximate the longitudinal axis 216. In examples, the illustrated arrangement of the distal end 234 may promote an easier mutual positioning between the shunt contact 104 and a hole of the shunt just before insertion. Moreover, in examples, before the shunt contact 104 is inserted into the sensing hole of the shunt, the arcuate surfaces 232 may extend, e.g., radially, beyond a diameter of the sensing hole. Accordingly, when the shunt contact is inserted into the hole, contact with the tapered distal end 234 will impart a force on the distal end 234 that at least partially causes the fins 230 to “bend” into the sensing hole under continued insertion.

[0037] As noted above, the shunt contact 104 is intended to be used in an electrical assembly, like the electrical assembly 100. In such an assembly, the first edge 220 of the standoff portion 112 contacts the circuit board 102 and the second edge 222 of the standoff portion 112 contacts the shunt 106. In examples, it may be desirable that the edges 220, 222 are flush with the respective surfaces of the circuit board 102 and the shunt 106, e.g., to ensure proper alignment. As best shown in FIG. 2A, the shunt contact 104 includes recesses 236 proximate a junction of blade 202 and the flaps 214. Specifically, the recesses 236 are illustrated as arcuate cutouts formed in the flaps 214. As will be appreciated, the recesses 236 will provide a small bit of clearance

between the circuit board 102 and the standoff portion 112, e.g., to ensure that no radius is present that would prevent flush contact of the first edge 220 with the (planar) surface of the board 102.

[0038] FIG. 2A also illustrates cutouts 238 formed proximate a junction of the shunt contacting portion 110 and the standoff portion 112. The cutouts 238 may serve a function similar to that of the recesses 236, e.g., to ensure that no radius is present that would prevent flush contact of the second edge 222 with the (planar) surface of the shunt 106. The cutouts 238 may also extend further longitudinally into the standoff portion 112 (compared to the recesses 236). The relatively deep cutouts 238 may aid in the formation of the fins 230. For instance, the fins 230 may be formed by “twisting” or “bending” a conductive material, e.g., sheet metal. The cutouts 238 may allow for some longitudinal distance or clearance that serves as a transition area to the “beginning” of the fins 230. In this manner, the fins 230 may be substantially uniform at any longitudinal positions in the shunt contacting portion 110, e.g., “below” the second edge 222 of the standoff portion 112 in the orientation of FIG. 2A. Moreover, the central portion 228 of the standoff portion 112, e.g., located laterally between the flaps 214 and longitudinally between the cutouts 238 and the board contacting portion 108 may be substantially planar and may facilitate some angular (back and forth) motion that allows the board contacting portion 108 to move relative to the shunt contacting portion 110. For instance, this relative movement may facilitate insertion of the board contacting portion 108 and/or the shunt contacting portion 110 into holes that have some positional misalignment and/or that are otherwise angled or tilted.

[0039] As will be appreciated from FIGS. 2B and 2C, the thickness, t_1 , of the board contacting portion 108, a thickness of the flaps 214, and the thickness, t_2 , of the fins 230 may be substantially the same or uniform. In examples, the shunt contact 104 may be formed from a single piece of material, e.g., a single sheet or strip of metal, or the like. In some examples, a single

manufacturing operation, e.g., a metal cutting and bending operation using a press or punch, may cut the outer profile of the shunt contact 104, create the bends 224, and/or “twist” or bend the fins 230, e.g., in a single action. Thus, the shunt contact can be made efficiently and with low cost. In other examples, the shape of the shunt contact 104 may be cut from a single piece of sheet metal or other material and one or more subsequent bending and/or twisting operations may be performed to form the bends 224 and the fins 230. Other manufacturing processes also may be appreciated by those having ordinary skill in the art, with the benefit of this disclosure.

[0040] FIGS. 3A and 3B are partial perspective and top views, respectively, showing the shunt contact 104 coupled to the circuit board 102. More specifically, as best shown in FIG. 3B, the circuit board 102 includes a slotted opening 302 formed through the circuit board 102. In examples, a conductive layer 304 is formed on the inner surface of the slotted opening 302. Without limitation, the slotted opening 302 may be a plated through hole or plated slot, as is conventionally known in the art.

[0041] As best shown in FIG. 3A, the blade 202 of the board contact portion 108 is inserted into the slotted opening 302 until the first edge 220 of the flaps 214 of the standoff portion 112 contacts a (lower) surface 306 of the circuit board 102 (and/or the bottom of the conductive layer 304). As also shown in FIG. 3A, the recesses 236 provide spacing between the surface 306 proximate the junction of the blade 202 and the standoff portion 112, e.g., to ensure flush contact of the first edge 220 with the surface 306.

[0042] The width, w_{slot} , of the slotted opening 302 may be only slightly larger than the thickness, t_l , of the blade 202 (shown in FIG. 2B). Accordingly, once the blade 202 is completely inserted into the opening 302 and the flaps 214 contact the surface 306, as in FIG. 3A, movement

of the shunt contact 104 relative to the circuit board 102 is minimized. In this position, the shunt contact 104 may be affixed to the circuit board 102, e.g., by soldering, potting, epoxy, or the like. Because the movement of the shunt contact 104 is severely limited prior to the affixing operation (e.g., soldering), the shunt contact 104 may be assumed to have the same angle as the angle of the slot 302 in the circuit board 102. This may be particularly important to ensure a precise angle of the fins 230 relative to the shunt 106, as detailed further herein.

[0043] FIGS. 4A and 4B are partial perspective and bottom views, respectively, showing the shunt contact 104 coupled to the shunt 106. More specifically, as best shown in FIG. 4B, the shunt 106 includes a sensing opening 402 formed through the shunt 106. In examples, the shunt 106 is made of a low resistance conductive material, as is conventionally known in the art.

[0044] FIG. 4B also shows the shunt contacting portion 110 disposed in the sensing opening 402. Specifically, in that figure, the outer surfaces 232 of the fins 230 are illustrated as contacting an inner surface of the sensing opening 402 at contact regions 404. As detailed above, the fins 230 have an elastic quality that biases the fins 230 generally outwardly relative to the longitudinal axis. Thus, the contact regions 404 are formed at locations at which the outer surfaces 232 of the fins 230 press against the inner surface of the sensing opening 402.

[0045] To illustrate the elastic nature of the fins 230, FIG. 4B also includes, in dashed lines, representations 230' of the fins 230 and representations 232' of the outer surfaces 232 of the fins in a normal or resting position, as in FIGS. 2A-2C. As shown by the representations 230', 232', extents of the fins 230 are normally positioned radially outward of the extents of the sensing opening 402. However, as the fins 230 are pressed into the sensing opening 402, the fins 230 compress or otherwise deform under pressure applied by the inner surface of the sensing opening

402. The fins 230, which are biased to the normal position shown by the representations 230', 232' apply a biasing force, e.g., at the contact regions 404 by the outer surfaces 232, to maintain the fins 230 in the sensing opening 402. As illustrated in FIG. 4B, in addition to compressing, radially inwardly, the fins 230 may also undergo a twisting, e.g., about an axis of the sensing opening 402.

[0046] As shown in FIG. 4A, the shunt contact 104 may be inserted into the sensing opening 402 to a depth at which the second edges 222 of the flaps 214 contact a surface 406 of the shunt 106. In examples, the second edges 222 make flush contact with the surface 406 of the shunt 106.

[0047] Thus, in examples of this disclosure, the shunt contacting portion 110 may be press fit into the sensing opening 402 and will remain in the opening 402 under a biasing force applied by the fins 230. Moreover, contact of the second edges 222 with the surface 406 of the shunt 106 will ensure a proper spacing of the shunt 106 from the circuit board 102, upon coupling of the board contacting portion 108 with the circuit board, generally as shown in FIGS. 3A and 3B, and as discussed above.

[0048] The shunt contact 104 described herein may provide improvements over conventional pins used to mount a circuit board, e.g., associated with a measuring device, to a shunt. For example, one conventional pin arrangement includes brazed paddles, e.g., bent metal structure that are brazed to a surface of the shunt. However, an interloping material under the brazed paddles can change due to heating and/or aging, and the resulting sensing point has been shown to travel from one edge of the paddle to the other. Another conventional arrangement includes a pin stacked in a terminal of a copper shunt, but in such an arrangement, it is not possible

to locate the contact point with certainty. Moreover, the electrical board that includes the circuit for the measurement apparatus cannot be readily soldered to either of the conventional pin types just described. For instance, if the electrical board is not sufficiently distanced from the shunt, the relatively low thermal resistance of the pins does not allow for reaching adequately high temperatures required for melting and flowing of the solder, thereby preventing formation of appropriate solder fillets. In contrast to these conventional pins, the shunt contact 104 may readily allow for defined and stable positioning for sensing of the shunt and the shunt contact 104 may be soldered to the electrical board using ordinary and conventional assembly techniques (e.g., soldering).

[0049] Modifications to the foregoing also are contemplated. For example, as discussed above, the recesses 236 may be formed proximate the junction of the board contacting portion 108 and the standoff portion 112 to ensure that no radius between those portions prevents flush contact of the first edges 220 with the surface 306 of the circuit board 102. FIGS. 5A and 5B are partial views showing alternative arrangements of the recesses 236.

[0050] FIG. 5A shows an arrangement of a modified recess 502 that may be used in place of the recesses 236 discussed above. Where the recesses 236 were formed as cutouts in the upper edge 220 of the flaps 214 in FIG. 2A, the recess 502 is formed in the second lateral side 206 of the board contacting portion 108. Although not shown in FIG. 5A, a corresponding recess may be formed in the first lateral side 204 of board contacting portion 108. As with the recesses 236, the recess 502 eliminates a radius proximate the junction of the board contacting portion 108 and the standoff portion 112.

[0051] FIG. 5B shows an arrangement of a second modified recess 504 that may be used in place of the recesses 236 discussed above. Where the recesses 236 were formed as cutouts only in the upper edge 220 of the flaps 214 in FIG. 2A, the recess 504 is formed in both the upper edge 220 of the flaps 214 and the second lateral side 206 of the board contacting portion 108. Although not shown in FIG. 5B, a corresponding recess may be formed in the first lateral side 204 of board contacting portion 108 and the non-illustrated instance of the flaps 214. As with the recesses 236, the recess 504 eliminates a radius proximate the junction of the board contacting portion 108 and the standoff portion 112.

[0052] In examples, one of the recesses 236, 502, 504 may be preferred based on one or more factors. For example, and without limitation, the configuration of the recess may be based at least in part on a fabrication method used to cut or otherwise form the shape of the shunt contact 104. Other recess configurations that facilitate full insertion of the board contacting portion 108 into a corresponding board opening will be appreciated by those having ordinary skill in the art, with the benefit of this disclosure. Moreover, in other instances the recess may not be included. For instance, the width, w , of the blade 202 and a length of the slot 302 into which the blade 202 may be inserted may be sized to provide sufficient clearance that a small radius between the lateral sides 204, 206 of the blade 202 and the first edges 220 can be accommodated in the slot.

[0053] As noted above, the shunt contact 104 according to this disclosure is intended for coupling a board, such as the circuit board 102, to a shunt, such as the shunt 106. In examples, the shunt 106 may be any of a number of conventional shunts and/or shunting elements. However, some aspects of this disclosure also relate to an improved shunt, as shown in FIG. 6. More specifically, FIG. 6 shows a shunt 600 that may be used as the shunt 106. The shunt 600 may be configured for use as both a resistive shunt and for use with sensing current via magnetic means.

[0054] As shown in FIG. 6, the shunt 600 is a substantially planar member extending longitudinally between a first end 602 and a second end 604 and extending laterally between a first side 606 and a second side 608. A center region 610 of the shunt separates the shunt longitudinally into a first region 612 extending between the first end 602 and the center region 610 and a second region 614 extending between the second end 604 and center region 610. In examples, the first region 612 and the second region 614 may be made of a highly conductive, low resistance material, such as copper or the like. Also in examples, the center region 610 may be made of a relatively higher resistance, temperature stable material, such as a copper alloy (which may be Manganin®, for example). In examples, the center region 610 and the first and second regions 612, 614 are joined together so as to form a continuous, uniform member that is free of irregularities, abrupt changes, and/or other features that would distort the direction, position, and/or magnitude of the current filaments (as discussed below). Without limitation, the regions 610, 612, 614 may be welded together, e.g., butt welded, electron beam welded, and/or the like, to create a uniform electrical interface between the regions 610, 612, 614.

[0055] As also illustrated in FIG. 6, the shunt 600 includes terminal openings 616 in the first and second regions 612, 614 proximate the ends 602, 604. The terminal openings 616 are configured for connecting the shunt to a circuit to be measured. For example, the terminal openings 616 may be sized to be placed on posts associated with an electrical system. Without limitation, the electrical system may include a high voltage and/or high current circuit to be measured and/or monitored using the shunt 600, such as in an electric vehicle system.

[0056] The shunt 600 also includes a plurality of sensing holes 618a, 618b, 618c, 618d extending through the shunt at locations proximate the center region 610. In the illustrated example, the sensing holes 618a, 618b are disposed in the first region 612 and the sensing holes

618c, 618d are disposed in the second region 614. Moreover, the sensing hole 618a and the sensing hole 618c are generally disposed at positions opposite each other, relative to the center region 610. Similarly, the sensing hole 618b and the sensing hole 618d are generally disposed at positions opposite each other, relative to the center region 610. For example, the sensing holes 618a, 618c may be equidistant from the first side 606 and the center region 610, and/or the sensing holes 618b, 618d may be equidistant from the second side 608 and the center region 610. In examples, the sensing holes 618a, 618c may comprise a pair of sensing holes used to determine a resistive voltage drop across the shunt 600, and/or the sensing holes 618b, 618d may comprise a pair of sensing holes used to determine a resistive voltage drop across the shunt 600. Although four instances of the sensing holes (two pairs) are illustrated in FIG. 6, in other examples, more or fewer sensing holes may be used in other examples. In examples, the shunt 600 may be formed in a single processing step, e.g., via a stamping operation, that makes the appropriate holes, cutouts, and/or the like.

[0057] In use, the shunt 600 may be attached to a power source via one of the terminal openings 616 and to a load via the other of the terminal openings 616. Then, a measuring device, such as a measuring device comprising the circuit board 102, may be attached to a pair of the sensing holes 618 (e.g., the sensing holes 618a, 618c or the sensing holes 618b, 618d) using the shunt contacts 104 described herein. As current passes from the power supply to the load in this example, the measuring device can measure a resistive voltage drop across the shunt 600 and determine a current based on the voltage drop. As noted above, because the board contacting portion 108 of the shunt contacts 104 is soldered to the circuit board 102, the shunt contacts 104 need only be pressed into the appropriate pair of sensing holes.

[0058] As noted above, the shunt 600 also includes features to facilitate sensing current using magnetic fields. More specifically, the shunt 600 includes first opposing notches 620 extending laterally inward from the first and second sides 606, 608 in the first region 612 and second opposing notches 622 extending laterally inward from the first and second sides 606, 608 in the second region 614. The first opposing notches 620 form a first necked portion 624 of the first region 612 the second opposing notches 622 form a second necked portion 626 of the second region 614.

[0059] The necked portions 624, 626 function as current concentrators, e.g., by restricting the width of the shunt and thus forcing current passing through the first and second regions 612, 614 through the respective necked portions 624, 626. Although not illustrated, a sensor, such as a hall-effect sensor, may be used to sense the magnitude of a magnetic field at the necked portions and determine a current at the necked portions based on the magnitude of the magnetic field.

[0060] While the shunt 600 may facilitate both resistive current measurement and magnetic current measurement, because of the necked portions 624, 626, current distribution near the sensing holes may be non-uniform. For example, FIGS. 7A and 7B are plan views of a portion of the shunt 600 including a portion of the first region 612, a portion the center region 610, a portion of the first necked portion 624, and the sensing hole 618a.

[0061] FIG. 7A also shows the (non-uniform) current density flowing through the first region 612. As shown, the current density is illustrated by a number of current filaments including a first current filament 702a, a second current filament 702b, and a third current filament 702c. As illustrated, the first current filament 702a extends generally longitudinally through the shunt 600, the second current filament 702b extends between the first current filament 702a and the sensing

hole 618a, and the third current filament 702c extends on a side of the sensing hole 618a opposite the second current filament 702b. In this examples, a width of the current filament represents a magnitude of the current filament. Thus, the magnitude of the current in the current filament 702c is smaller than the magnitude of the current in the current filament 702b, simply because the current filament 702c travels a longer distance through the material, and thus will encounter higher resistance.

[0062] FIG. 7B shows an instance of the shunt contact 104 disposed in the sensing hole 618a. In examples of this disclosure, the shunt contact 104 may be arranged at a rotational angle 704 that improves sensing. In the example of FIG. 7B, the shunt contact 104 is rotationally disposed within the sensing hole 618a to position the contact regions 404 at positions based at least in part on the current density in the shunt 600. As detailed further herein, the angle 704 may be determined to ensure that the resistance versus temperature behavior of the shunt 600 is not dependent on which of the fins 230 makes better electrical contact.

[0063] FIG. 8 is an electrical schematic model 800 including the shunt 600 in the neighborhood of the sensing hole 618a, with the shunt contact 104 inserted into the sensing hole 618a, as in FIG. 7B. More specifically, the model 800 of FIG. 8 shows a first current source 802 representative of the third current filament 702c and a second current source 804 representative of the second current filament 702b. The model 800 also includes a first contact point 806 representing the contact region 404 at which the shunt contact 104 contacts the inner surface of the sensing hole 618a proximate the third current filament 702c and a second contact point 808 representing the contact regions 404 proximate the second current filament 702b. The model 800 also includes a first resistor 810 representative of a resistance in the area of the third current

filament 702c and a second resistor 812 representative of a resistance in the area of the second current filament 702b.

[0064] The model 800 also includes a third resistor 814 associated with a first modeled contact resistance of the shunt contact 104 and a fourth resistor 816 associated with a second modeled contact resistance of the shunt contact 104. Finally, the model 800 includes a representation 818 of the board contacting portion 108, which may be a lead/tail connected to a measuring apparatus, as described herein.

[0065] As will be appreciated from the model 800, if the two contact points 806, 808 have exactly the same voltage potential, a possible shift of the contact points from one side to the other (e.g., due to changes in the values of the resistances associated with the third and fourth resistors 814, 816) will not affect the voltage developing on the lead/tale connection embodied as the board contacting portion 108. According to aspects of this disclosure, the balance of the voltage potential may be achieved by ensuring that a resistance of the first resistor 810 is considerably larger than a resistance of the second resistor 812, with these resistances inversely proportional to the current in the filaments 702c, 702b.

[0066] In aspects of this disclosure, these dissimilar resistances may be achieved by installing the shunt contacting portion 110 of the shunt contact 104 at the angle 704 shown in FIG. 7B. In examples, the longer distance through the material (along the direction of the current flow) may correspond to a higher resistance, so the angle 704 may be selected such that the contact regions 404 are situated along the current filaments in a manner that the distance travelled through the material is substantially equal and/or that the voltage at the contact regions 404 is the same. An appropriate selection of the angle 704 allows the shunt to have the same resistance vs

temperature characteristics irrespective of which point 806 or 808, and the corresponding modelled resistances 814/816 has the best contact (electrical conductivity). In other words, the proper selection of the angle 704 makes the resistance vs temperature behavior of the shunt substantially the same, regardless of which of the fins 230 makes better electrical contact. In some instances, the exact determination of the locations for the contact regions 404, e.g., the exact angle 704, may be determined theoretically using simulation tools, finite element analysis, and/or the like. The angle may also (or alternatively) be determined and/or verified using physical testing of the shunt at the angle 704.

[0067] In a system using the shunt 600, a circuit board, such as the circuit board 102 may have two (or more) instances of the slots 302 spaced in accordance with a spacing between a pair of the sensing holes 618. Moreover, the slots 302 may be angled, e.g., relative to each other and/or to some reference line. Instances of the shunt contact 104 may be coupled to the board, e.g., by inserting the board connection portion 108 of the shunt through the slots 302 and/or soldering the board connection portion 108 to the slot. As will be appreciated, once coupled to the board, the physical positioning, including rotational orientation, of the shunt contacts 104 may be established. The shunt contacts 104 are then pressed into the sensing holes to generally form the electrical assembly 100 discussed above.

[0068] FIG. 9 is a top view of a portion of an example of a circuit board 900, which may correspond to the circuit board 102 detailed herein. For example, the circuit board 900 may be configured for use with the shunt 600.

[0069] The circuit board 900 includes a first slot 902a and a second slot 902b (collectively, herein, the slots 902), each generally corresponding to an instance of the slot 302 discussed above.

The slots 902 are sized to receive instances of the shunt contact 104. Moreover, the slots 902 are positioned to align connected instances of the shunt contact 104 with instances of sensing holes. When used with the shunt 600, the first and second slots 902a, 902b of the circuit board 900 may align instances of the shunt contact with the sensing holes 618a, 618c or with the sensing holes 618b, 618d, for example. As also illustrated, the slots 902 are angled, e.g. relative to an axis 904. As described above, it may be desirable to control the positions of the contact regions between the shunt contacts 108 and the sensing holes, e.g., to ensure proper sensing. More specifically, the angle of the slots 902 in the circuit board 900 will dictate the rotational position of the shunt contact 104, and thus the positions of the contact regions within the sensing holes.

[0070] In the example of FIG. 9, the first slot 902a, e.g., a longitudinal dimension of the first slot 902a, is angled relative to the axis 904 by a first angle 906, and the second slot 902b, e.g., a longitudinal dimension of the second slot 902b, is angled relative to the axis 904 by a second angle 908. In examples, the first angle 906 may be different from the second angle 908. In such a case, the first slot 902a and the second slot 902b are not symmetrical about the axis 904. The circuit board 900 may include the different angles 906, 908 despite the shunt with which the circuit board 900 is used being symmetrical about an axis corresponding to the axis 904, e.g., a lateral axis. For example, the shunt 600 is symmetrical about its lateral axis, and the circuit board 900 may be configured for use with the shunt 600. More specifically, and as noted above with regard to FIG. 4B, when the shunt contacting portion 110 is inserted into a sensing hole of the shunt, the fins 230 may undergo a degree of rotation or twisting. As will be appreciated, this rotation is relative to the sensing hole as well as relative to the board contacting portion 108. Thus, the angles 906, 908 may be formed, e.g., at the time of fabricating the circuit board 900, to account for the twisting of the fins 230 of the shunt contacts 104, thereby positioning the contact regions as

generally discussed above with respect to FIG. 7B. Stated differently, the different angles 906, 908 may be used to ensure that the fins 230 are positioned in accordance with the angle 704 illustrated in FIG. 7B.

[0071] Although in this example, the different angles 906, 908 are used to account for twisting of the shunt contacts, in other examples, the different angles 906, 908 may be substantially the same. For example, two (or more) types of the shunt contacts described herein may be formed. For instance, a first type may be formed that rotates counterclockwise when compressed, and a second type may be formed that rotates clockwise when compressed. In one type, the fins may form an S-shape, and, in the other type, the fins may form an inverse, reverse, or backward S-shape. In these examples, the angles 906, 908 may be substantially the same and one of the types of the shunt contact 104 may be used in the first slot 902a and the other of the types may be used in the second slot 902b. Even in this example, the angles 906, 908 may be determined to account for the twisting of the fins 230.

[0072] As will be appreciated from the foregoing, the rotational angle of the shunt contact 104 relative to the sensing holes 618 will dictate the relative position of the contact regions 404. Altering the positioning of the contact regions 404 can help mitigate non-uniform current density through a shunt, like the shunt 600. As will be appreciated, in other examples in which the shunt does not include the necked portions 624, 626, the current density may be substantially uniform through the shunt. In such cases, the angle 704 may be 0-degrees, e.g., the contact regions 404 may be spaced equidistant from a longitudinal end of the shunt. As discussed above in connection with FIG. 9, the angles 906, 908 may be offset relative to the angle 704 to account for the rotational twisting of the fins 230 of the shunt contact 104.

[0073] As will be appreciated from the foregoing, aspects of this disclosure may provide improved electrical sensing devices. For example, a shunt contact 104 according to the present disclosure may facilitate an easier to assembly and/or configurable resistive shunting device. In examples the shunt contact 104 can be attached to a circuit board 102, 900, e.g., associated with a measurement circuit, via conventional and repeatable techniques, such as soldering. The shunt contact 104 can also facilitate a press fit connection with a sensing hole of a shunt, like the shunts 106, 600. The press fit connection may be enabled by the compressible or “springy” fins 230. The fins 230 may facilitate two points of contact, e.g., the contact regions 404, with the inner wall of a sensing hole of the shunt. The contact regions 404 may be straight lines (or narrow strips) that extend generally parallel to an axis of the sensing hole. Which of the contact regions most influences the voltage that flows through the shunt contact 104 may not be known. Thus, by providing for angular rotation of the shunt contact 104, the voltages can be balanced as discussed above in connection with FIGS. 7A, 7B, and 8.

[0074] While the subject technology has been described with respect to preferred embodiments, those skilled in the art will readily appreciate that various changes and/or modifications can be made to the subject technology without departing from the spirit or scope of the subject technology. For example, each claim may depend from any or all claims in a multiple dependent manner even though such has not been originally claimed.

WHAT IS CLAIMED IS:

1. A shunt contact comprising:
a board contacting portion configured for coupling to a circuit board;
a shunt contacting portion configured for press fitting into an opening of a shunt; and
a standoff portion extending between the board contacting portion and the shunt contacting portion, the standoff portion comprising one or more flaps extending laterally relative to the board contact and the shunt contact, the one or more flaps extending longitudinally between a first edge proximate the board contacting portion and a second edge proximate the shunt contacting portion.
2. The shunt contact of claim 1, wherein the board contacting portion comprises a blade that is substantially planar.
3. The shunt contact of claim 1, further comprising an undercut proximate a junction of the board contacting portion and the first edge of the one or more flaps of the standoff portion.
4. The shunt contact of claim 1, wherein the shunt contacting portion comprises at least one fin configured to flex under a force applied along a radial direction.
5. The shunt contact of claim 4, wherein the at least one fin comprises a first arcuate fin and a second arcuate fin configured in a substantially S-shaped arrangement.

6. The shunt contact of claim 1, wherein a distal edge of the shunt contacting portion spaced from the standoff portion is angled.

7. The shunt contact of claim 1, wherein the standoff portion comprises a first flap extending in a first lateral direction and a second flap extending in a second lateral direction.

8. The shunt contact of claim 7, wherein at least one of the first flap or the second flap includes a bend proximate a distal end of the at least one of the first flap or the second flap.

9. The shunt contact of claim 1, wherein the board contacting portion, the shunt contacting portion, and the standoff portion are formed from a single sheet of metal.

10. An electrical assembly comprising:
a circuit board having one or more conductive openings;
a shunt having one or more sensing openings; and
a shunt contact electrically coupled to the circuit board and to the shunt, the shunt contact comprising:

a board contacting portion disposed in a conductive opening of the one or more conductive openings of the circuit board;

a shunt contacting portion press fit into a sensing opening of the one or more sensing openings of the shunt; and

a standoff portion extending between the board contacting portion and the shunt contacting portion, the standoff portion comprising one or more flaps extending

longitudinally from a first edge contacting a surface of the circuit board to a second edge contacting a surface of the shunt, the standoff portion spacing the circuit board from the shunt by a distance between the first edge and the second edge.

11. The electrical assembly of claim 10, wherein:
the board contacting portion is configured as a blade; and
the conductive opening in the circuit board comprises a plated slot sized to receive the blade.

12. The electrical assembly of claim 10, wherein the board conducting portion is soldered to the circuit board proximate the conductive opening.

13. The electrical assembly of claim 10, further comprising an undercut proximate a junction of the board contacting portion and the first edge of the one or more flaps of the standoff portion, the undercut facilitating contact of the first edge of the one or more flaps with the surface of the circuit board.

14. The electrical assembly of claim 10, wherein the shunt contact comprises at least one fin configured to flex under a force applied along a radial direction by an inner surface of the opening of the shunt.

15. The electrical assembly of claim 14, wherein a surface of the at least one fin contacting the inner surface of the opening of the shunt is arcuate and contacts an arcuate portion

of the inner surface of the opening of the shunt along a first contact region and along a second contact region.

16. The electrical assembly of claim 15, wherein:

a rotational position of the at least one fin in the sensing opening of the shunt is determined based at least in part on a current distribution through the shunt.

17. The electrical assembly of claim 16, wherein:

the shunt comprises at least one necked region that concentrates current passing through the shunt; and

the rotational position of the at least one fin in the sensing opening of the shunt is determined to substantially balance a voltage between the first contact region and the second contact region.

18. The electrical assembly of claim 10, wherein the shunt comprises:

a central region separating a first region from a second region, the central region having a relatively higher resistance than the first region and the second region;

a first sensing opening of the one or more sensing openings extends through the first region; and

a second sensing opening of the one or more sensing openings extends through the second region.

19. The electrical assembly of claim 18, wherein:

the shunt contact comprises a first shunt contact;

the circuit board comprises a first conductive opening of the one or more conductive openings and a second conductive opening of the one or more conductive openings; and

the first conductive opening is spaced from the second conductive opening by a distance corresponding to a distance between the first sensing opening and the second sensing opening of the shunt such that the first shunt contact is coupled to the first conductive opening and to the first sensing opening and a second shunt contact is coupled to the second conductive opening and to the second sensing opening.

20. The electrical assembly of claim 19, wherein:

the first conductive opening and the second conductive opening comprise a first slot and a second slots;

the first slot is angled relative to the second slot to establish a first rotational position of the shunt contacting portion of the first shunt contact in the first sensing opening and a second rotational position of the shunt contacting portion of the second shunt contact in the second sensing opening;

the first slot is angled relative to the first rotational position to account for a relative rotation of the shunt contacting portion of the first shunt contact resulting from compression of the shunt contacting portion of the first shunt contact; and

the second slot is angled relative to the second rotational position to account for a relative rotation of the shunt contacting portion of the second shunt contact resulting from compression of the shunt contacting portion of the second shunt contact.

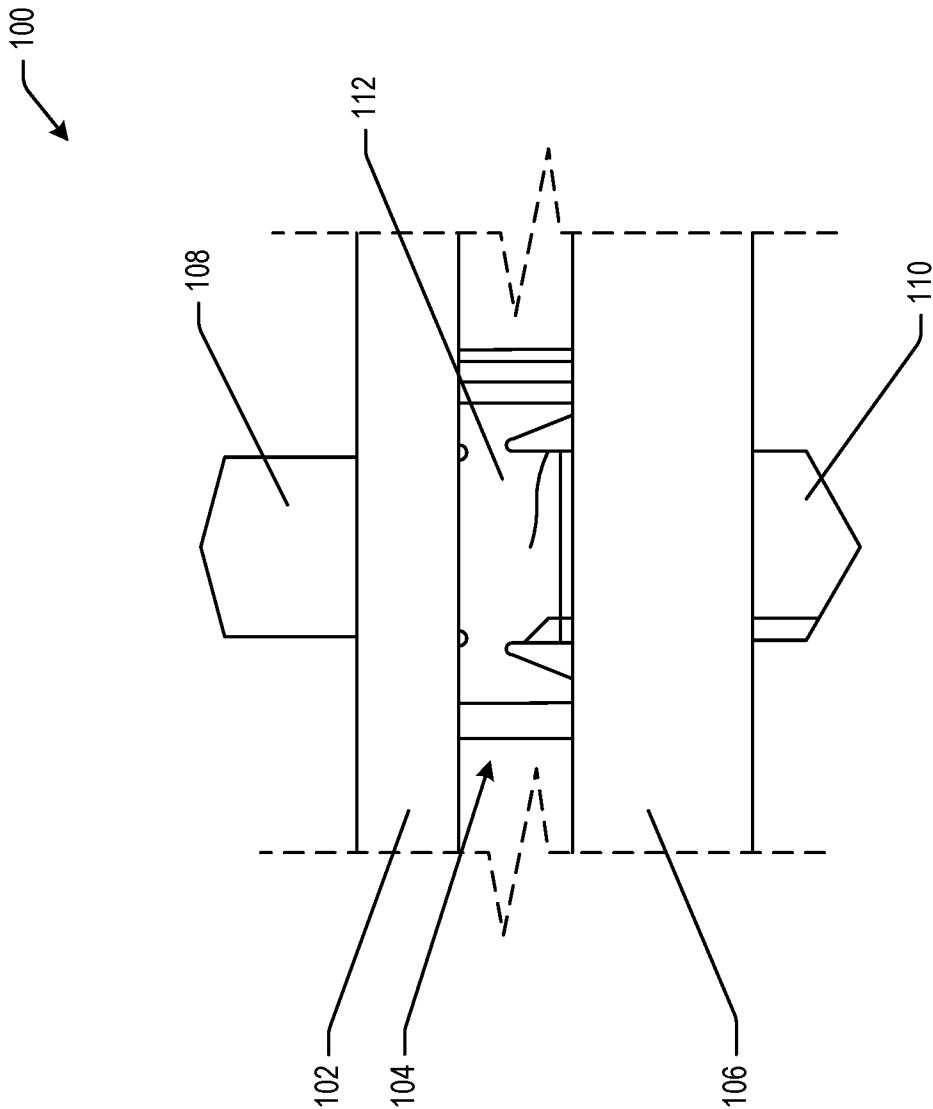


FIG. 1

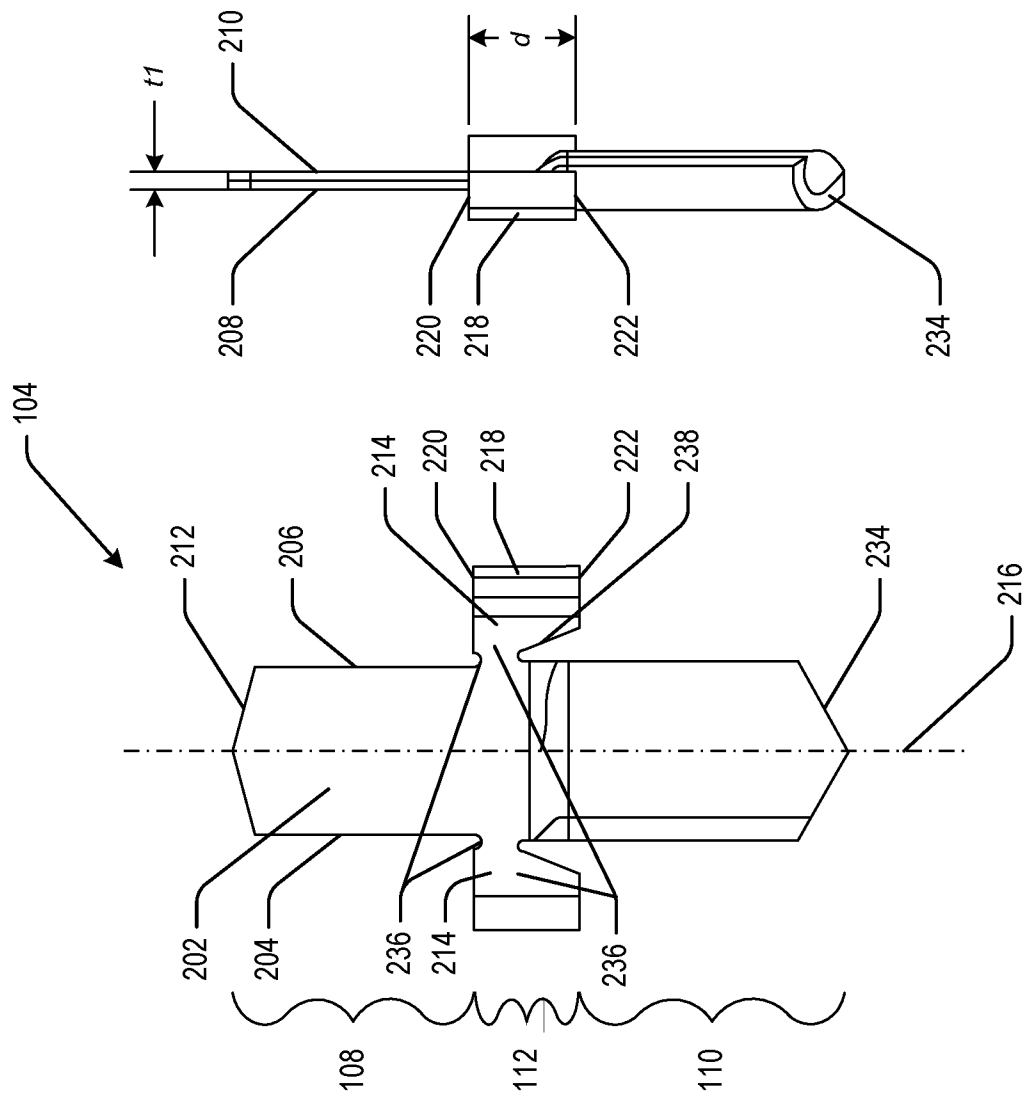


FIG. 2A

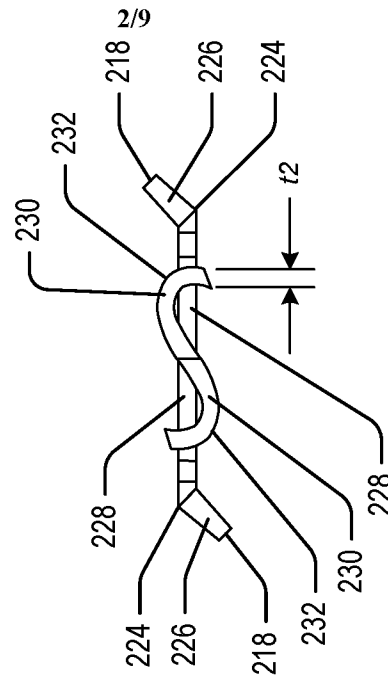


FIG. 2C

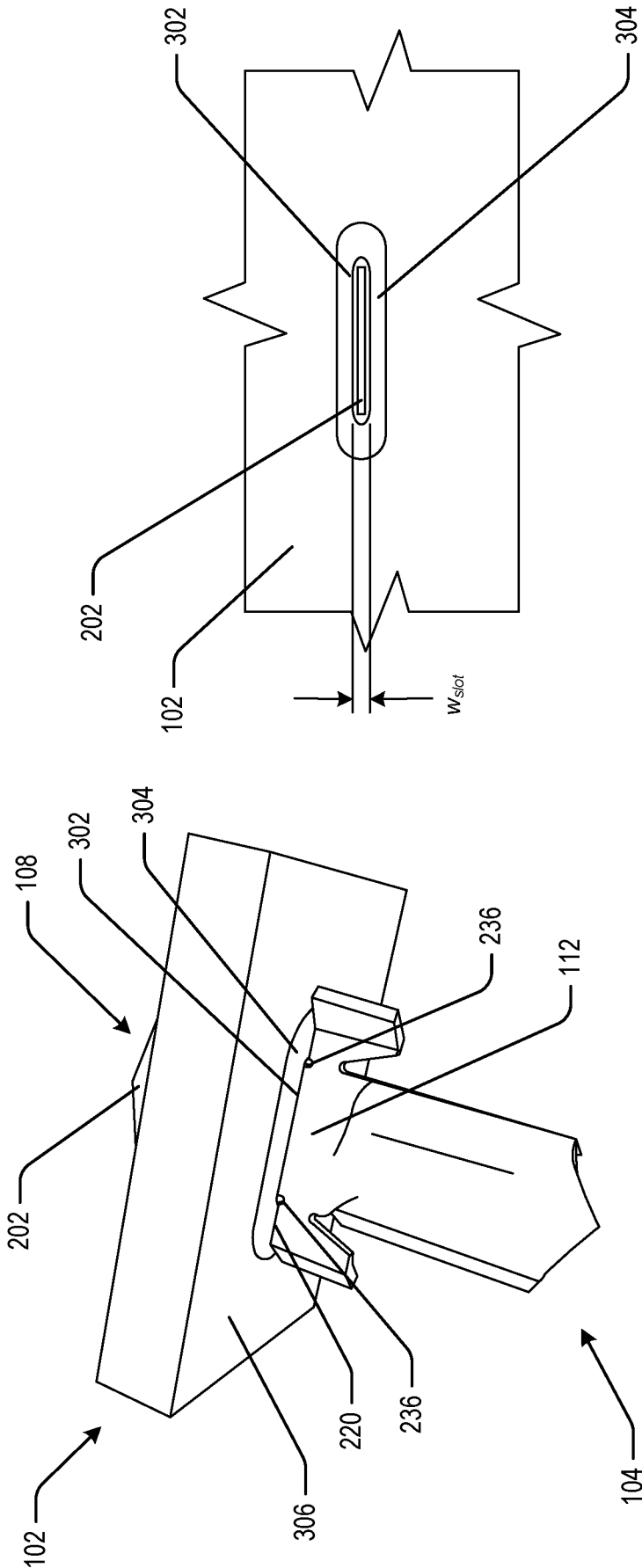


FIG. 3B

FIG. 3A

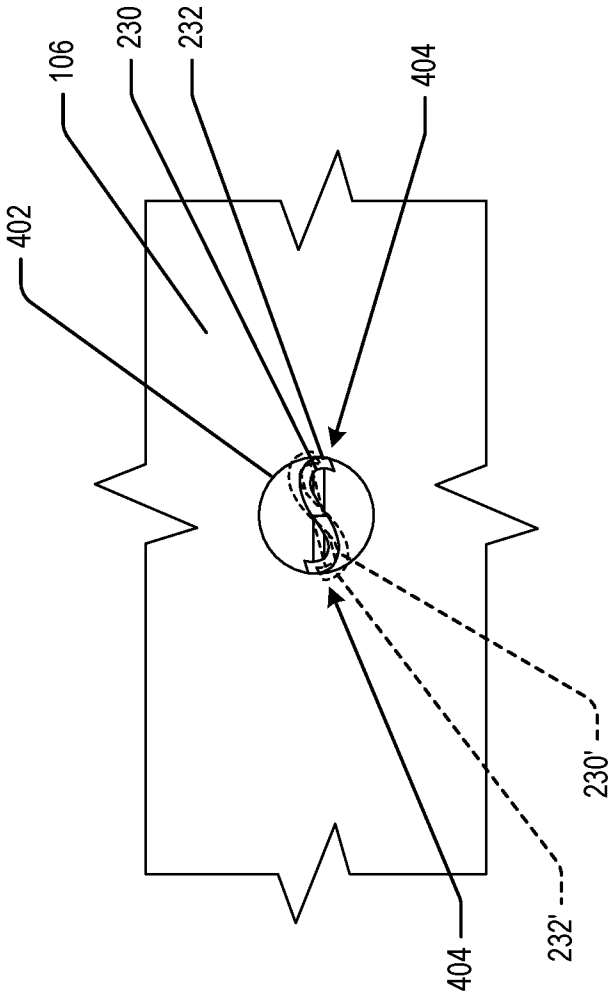


FIG. 4A

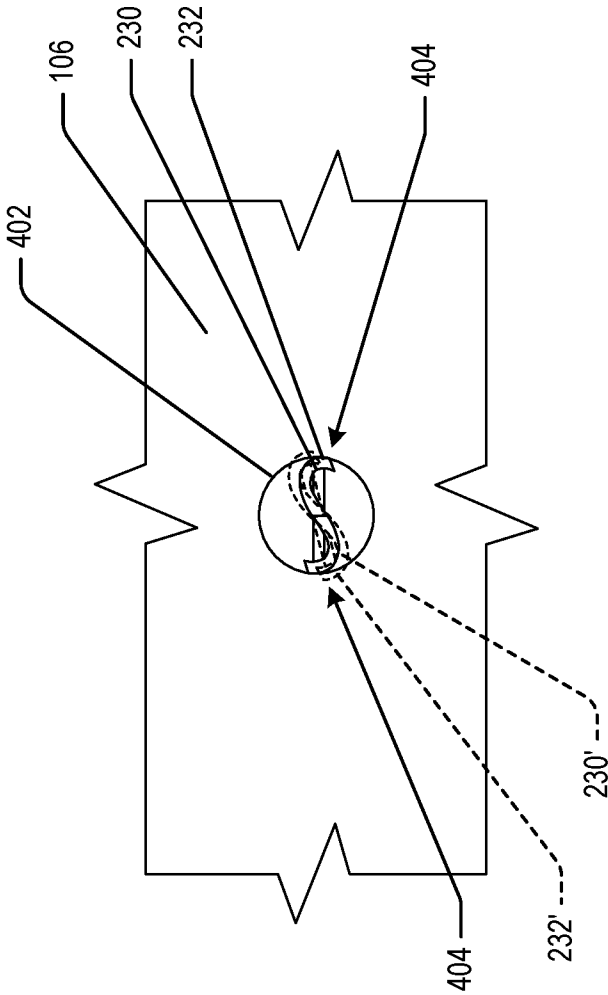


FIG. 4B

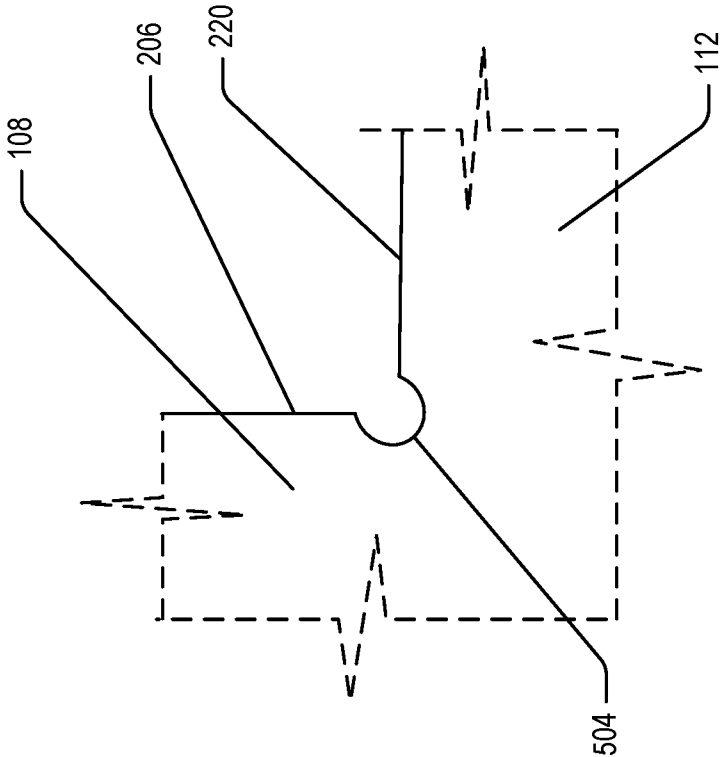


FIG. 5A

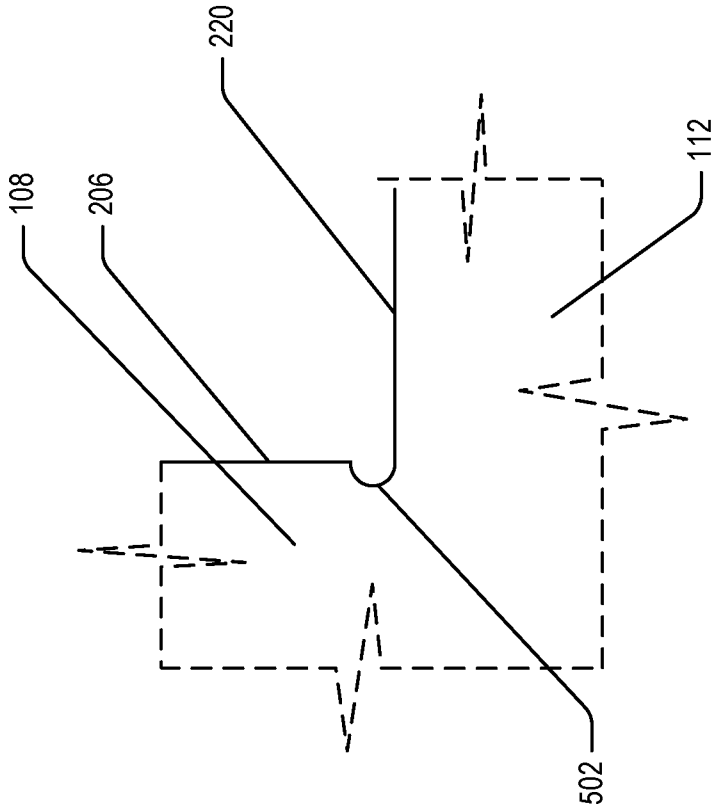


FIG. 5B

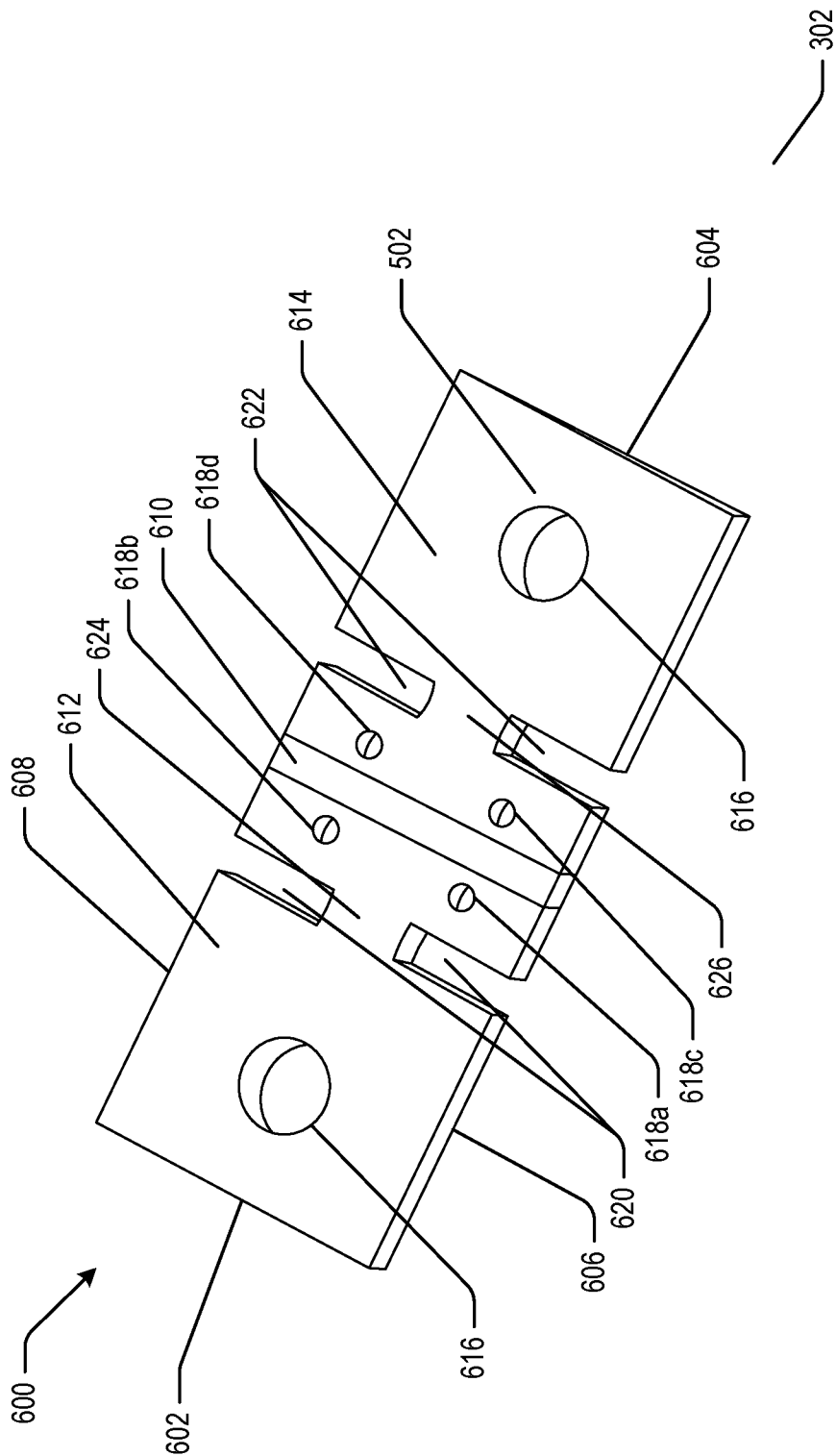


FIG. 6

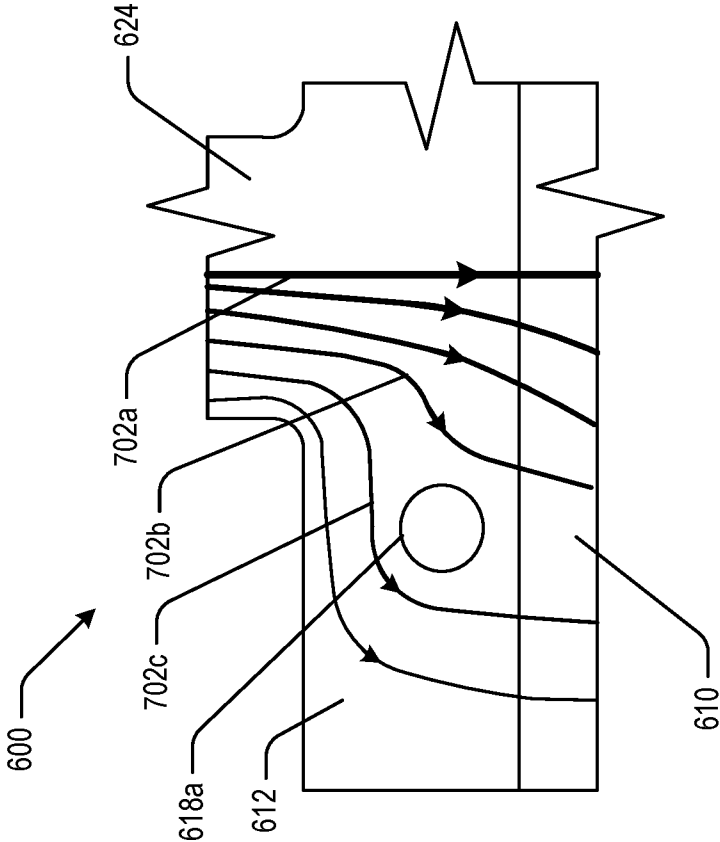


FIG. 7A

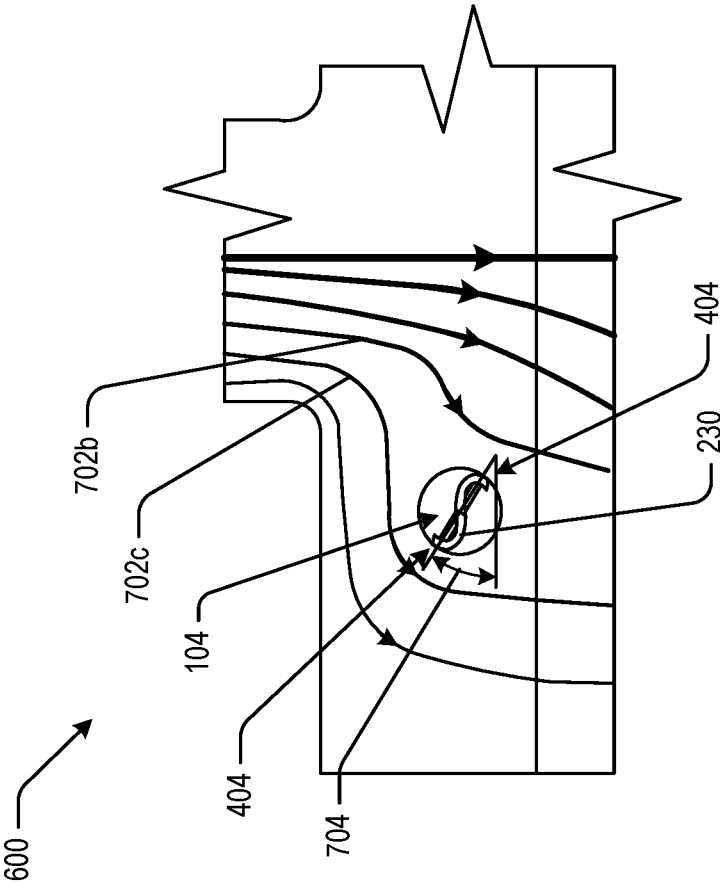


FIG. 7B

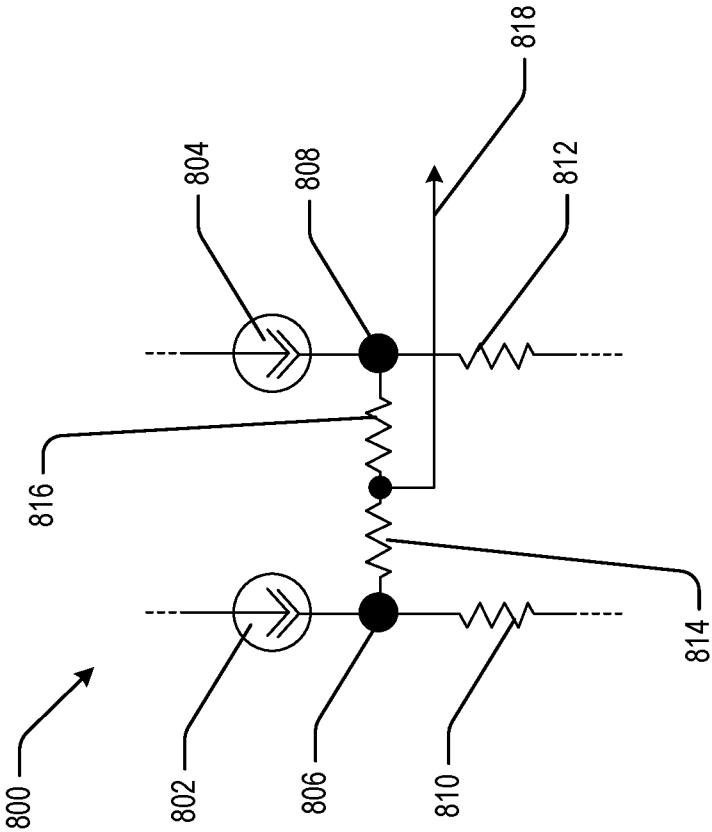


FIG. 8

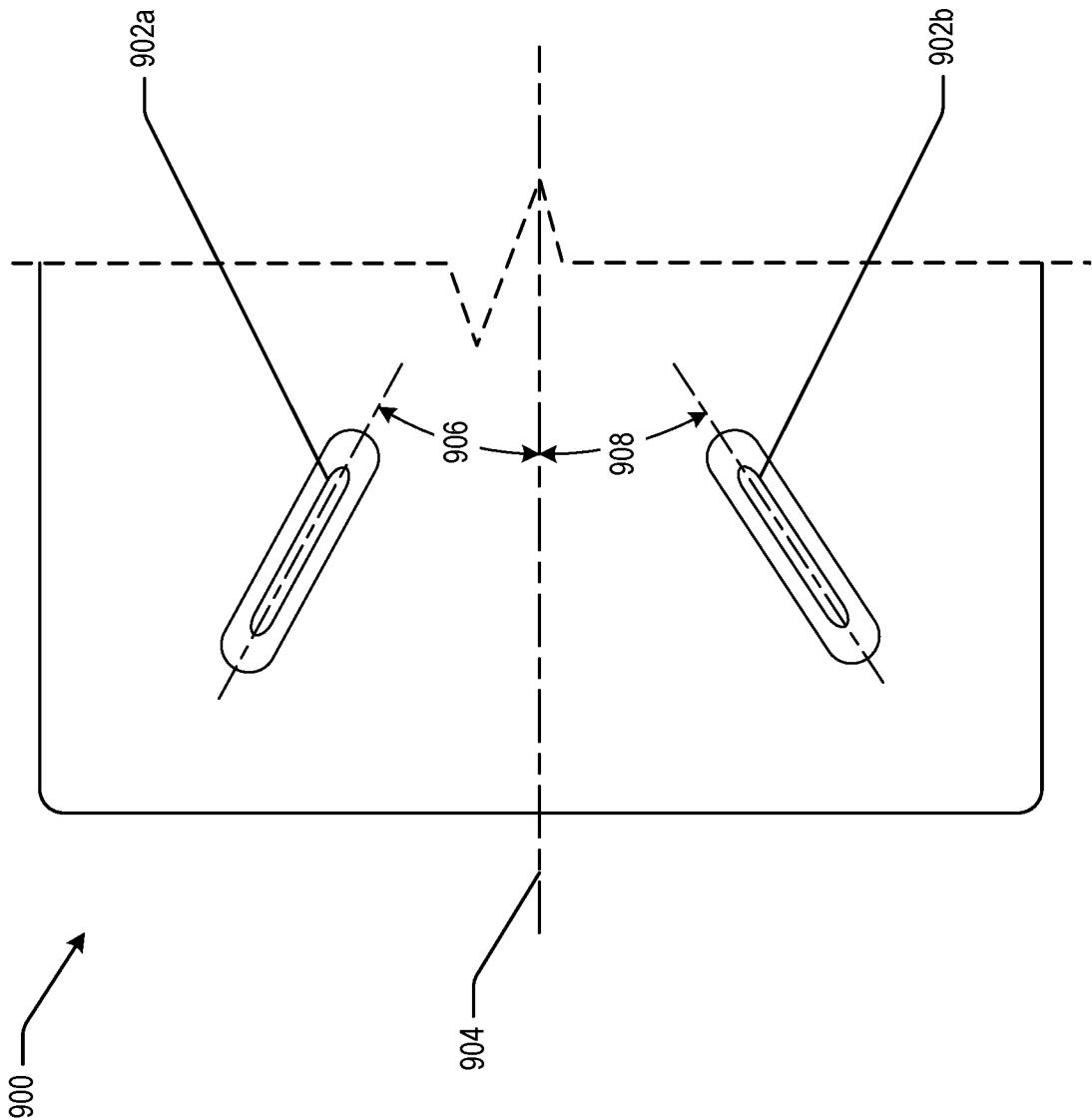


FIG. 9