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[Continued on next page]

(54) **Title**: INTEGRATED CIRCUIT PACKAGE HAVING A SPLIT LEAD FRAME

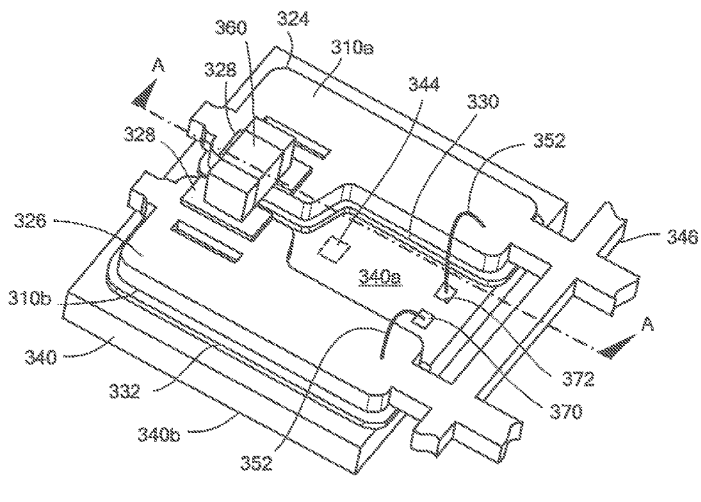

FIG. 11A

(57) **Abstract**: A magnetic field sensor includes a lead frame (310) having a plurality of leads (314, 316), at least two of which have a connection portion (334, 336) and a die attach portion (324, 326). A semiconductor die (340) is attached to the die attach portion of the at least two leads. The sensor further includes at least one wire bond (352) coupled between the die and a first surface (310a) of the lead frame. The die is attached to a second, opposing surface (310b) of the lead frame in a lead on chip configuration. In some embodiments, at least one passive component (360) is attached to the die attach portion of at least two leads.

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INTEGRATED CIRCUIT PACKAGE HAVING A SPLIT LEAD FRAME

FIELD OF THE INVENTION

[0001] This invention relates generally to integrated circuit packaging and, more particularly, to an integrated circuit package having a split lead frame.

BACKGROUND OF THE INVENTION

[0002] Techniques for semiconductor packaging are well known in the art. In general, a semiconductor die is cut from a wafer, processed, and attached to a die attach pad of a lead frame. The subassembly may then be overmolded with a plastic or other insulative and protective material to form an integrated circuit (IC) package.

[0003] After packaging, the IC may then be placed on a circuit board with other components, including passive components such as capacitors, resistors, and inductors, which can be used for filtering and other functionality. For example, in the case of a magnetic field sensor integrated circuit containing a magnetic field sensing element, components such as capacitors are often required to reduce noise and enhance EMC (electromagnetic compatibility).

[0004] Magnetic field sensors including a magnetic field sensing element, or transducer, such as a Hall Effect element or a magnetoresistive element, are used in a variety of applications to detect aspects of movement of a ferromagnetic article, or target, such as proximity, speed, and direction. Illustrative applications include, but are not limited to, a magnetic switch or "proximity detector" that senses the proximity of a ferromagnetic article, a proximity detector that senses passing ferromagnetic articles (for example, magnetic domains of a ring magnet or gear teeth), a magnetic field sensor that senses a magnetic field density of a magnetic field, and a current sensor that senses a magnetic field generated by a current flowing in a current conductor. Magnetic field sensors are widely used in automobile control systems, for example, to detect ignition timing from a position of an engine crankshaft and/or camshaft, and to detect a position and/or rotation of an automobile wheel for anti-lock braking systems.

[0005] In applications in which the ferromagnetic target is magnetic or of a hard ferromagnetic material, a magnetically permeable concentrator or magnetic flux guide is sometimes used to focus the magnetic field generated by the target on the magnetic field transducer, thus increasing the sensitivity of the sensor, allowing the use of a smaller magnetic target, and/or allowing the magnetic target to be sensed from a larger distance (i.e., a larger airgap). In other applications, in which the ferromagnetic target is not magnetic, a permanent magnet, sometimes referred to as a back bias magnet, may be used to generate the magnetic field that is then altered by movement of the target.

[0006] In some applications it is desirable to provide a back bias magnet with two magnetic poles on the magnet surface adjacent to the magnetic field transducer. For example, as described in a U.S. Patent No. 5,781,005 entitled "Hall-Effect Ferromagnetic-Article-Proximity Sensor," which is assigned to the Assignee of the subject application, the near presence of opposite poles serves to short out the lines of flux when no ferromagnetic article is present, thereby presenting a significant and easily recognizable difference between an article present (e.g., gear tooth present) condition and an article absent (e.g., gear valley present) condition and maintaining a low magnetic flux density baseline regardless of airgap. Because of the easily recognizable difference in the magnetic field signal, these types of arrangements are advantageous for use in sensors in which it is necessary to detect the presence/absence of a magnetic article, such sensors sometimes being referred to as True Power On Sensors, or TPOS, sensors.

[0007] Generally, back bias magnets and concentrators are held in place relative to the magnetic field sensing element by mechanical means, such as an adhesive as shown in a U.S. Patent No. 6,265,865 entitled "Single Unitary Plastic Package for a Magnetic Field Sensing Device," which is assigned to the Assignee of the subject application. Such mechanical positioning can lead to performance variations, such as sensitivity variations, from device to device due to position tolerances. Thus, it may be advantageous to manufacture the sensor so that the sensor and the back bias magnet or concentrator are integrally formed, thereby eliminating position tolerances. A magnetic field sensor of this type is described in a U.S. Patent Application Publication No. 2010/0141249 entitled "Magnetic Field Sensors and Methods for Fabricating the Magnetic Field Sensors," which is also assigned to the Assignee of the subject application and in which a concentrator or magnet may be formed by a liquid encapsulant or a combination of a liquid encapsulant and permanent magnet in a cavity on the side of the sensor opposite the target.

[0008] While the use of a back bias magnet is advantageous in certain applications, the hard magnetic material used to form the magnet is relatively expensive and represents a significant part of the overall cost of the sensor.

[0009] There are many package types and fabrication techniques in use for providing integrated circuit magnetic field sensors. For example, the semiconductor die in which the magnetic field sensing element is formed may be attached to a lead frame by various techniques, such as with an adhesive tape or epoxy, and may be electrically coupled to the lead frame by various techniques, such as with solder bumps or wire bonding. Also, the lead frame may take various forms and the semiconductor die may be attached to the lead frame in an orientation with the active semiconductor surface (i.e., the surface in which the magnetic field sensing element is formed) being adjacent to the lead frame in a so called "flip-chip" arrangement, with the active semiconductor surface opposite the lead frame surface in a so called "die up" arrangement, or with the semiconductor die positioned below the lead frame in a so called "Lead on Chip" arrangement.

[0010] Molding is often used in fabricating integrated circuit magnetic field sensors to provide the protective and electrically insulative overmold to the semiconductor die. Transfer molding has also been used to form two different molded portions for various reasons. For example, in a U.S. Patent No. 7,816,772 entitled "Methods and Apparatus for Multi-Stage Molding of Integrated Circuit Package" which is assigned to the Assignee of the subject application, a first molded structure is formed over the semiconductor die to protect wire bonds and the device is overmolded with a second molded structure formed over the first molded structure. In a U.S. Patent Application Publication No. 2009/0140725 entitled "Integrated Circuit Including Sensor having Injection Molded Magnetic Material," an injection molded magnetic material encloses at least a portion of a magnetic field sensor.

[0011] Molding, while providing a cost effective fabrication technique, can present challenges, such as removal of the device from the mold in a manner that does not subject the device to deleterious stresses.

SUMMARY OF THE INVENTION

[0012] A magnetic field sensor includes a lead frame having a plurality of leads, at least two of which have a connection portion and a die attach portion and a semiconductor die attached to the die attach portion of the at least two leads. A non-conductive mold material may enclose the semiconductor die and the die portion of the at least two leads.

[0013] A wire bond or other electrical connection mechanism may be used to electrically connect the semiconductor die to the die attach portion of at least one of the leads. In some embodiments, a wire bond is coupled between the semiconductor die and a location of a lead die attach portion distal from the respective connection portion of the lead. Alternatively or additionally, a wire bond may be coupled between the semiconductor die and a location of the lead die attach portion proximal to the respective connection portion of the lead.

[0014] A passive component may be coupled to at least two of the plurality of leads. In some embodiments, the passive component is coupled to the die attach portion of at least two leads. One or more passive components may additionally or alternatively be coupled to the connection portion of at least two leads. In one illustrative example, the passive component is a capacitor, but other types of passive components, such as resistors, inductors, and diodes as examples, are possible.

[0015] According to a further aspect, at least one lead has a first portion that is separated from a second portion of the lead and the magnetic field sensor further includes a passive component coupled between the first portion and second portion of the lead. With this arrangement, the passive component is electrically coupled in series or "in-line" with the respective lead. In one illustrative example, the passive component is a resistor, but other types of passive components, such as capacitors, inductors, and diodes as examples, are possible.

[0016] Additional described features include one or more slots in the die attach portion of at least one of the plurality of leads, one or more widened portions of the connection portion of at least one of the plurality of leads, and a ferromagnetic mold material secured to a connection portion of at least one of the leads.

[0017] A magnetic field sensor includes a lead frame having a plurality of leads, at least two of which have a connection portion and a die attach portion, a semiconductor die attached to the die attach portion of the at least two leads, and at least one wire bond coupled between the die and a first surface of the lead frame, wherein the die is attached to a second, opposing surface of the lead frame. A non-conductive mold material may enclose the semiconductor die and the die attach portion of the at least two leads.

[0018] The die attach portion of the at least two leads may be configured to expose a portion of the die to which the at least one wire bond is coupled. For example, the die may include at least two bond pads disposed between and exposed by the configuration of the die attach portion of the at least two leads.

[0019] A passive component may be coupled to at least two of the plurality of leads. In some embodiments, the passive component is coupled to the die attach portion of at least two leads. One or more passive components may additionally or alternatively be coupled to the connection portion of at least two leads. In one illustrative example, the passive component is a capacitor, but other types of passive components, such as resistors, inductors, and diodes, and passive networks, as examples, are possible.

[0020] According to a further aspect, a ferromagnetic mold material may be secured to a portion of the non-conductive mold material. The ferromagnetic mold material may comprise a soft or hard ferromagnetic material as examples and may function in the manner of a concentrator or back bias magnetic, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] The foregoing features of the invention, as well as the invention itself may be more fully understood from the following detailed description of the drawings, in which:

[0022] FIG. 1 is a plan view of a split lead frame;

[0023] FIG. 2 is a perspective view of a magnetic field sensor integrated circuit containing the split lead frame of FIG. 1 during fabrication;

[0024] FIG. 3 is a perspective view of the packaged magnetic field sensor integrated circuit of FIG. 2;

[0025] FIG. 4 is a perspective view of the packaged magnetic field sensor integrated circuit of FIG. 3 with leads bent for assembly;

[0026] FIG. 5 is a plan view of an alternative split lead frame;

[0027] FIG. 6 is a perspective view of a magnetic field sensor integrated circuit containing the split lead frame of FIG. 5 during fabrication;

[0028] FIG. 7 is a perspective view of the packaged magnetic field sensor integrated circuit of FIG. 6;

[0029] FIG. 8 is a plan view of a further alternative split lead frame;

[0030] FIG. 9 is a perspective view of a magnetic field sensor integrated circuit containing the split lead frame of FIG. 8 during fabrication; and

[0031] FIG. 10 is a plan view of an alternative packaged magnetic field sensor integrated circuit

[0032] FIG. 11 is a plan view of another alternative split lead frame;

[0033] FIG. 11A is a perspective view of a magnetic field sensor integrated circuit containing the split lead frame of FIG. 11 during fabrication; and

[0034] FIG. 11B is a cross-sectional view of the integrated circuit of FIG. 11A taken along line A-A of FIG. 11A.

DETAILED DESCRIPTION OF THE INVENTION

[0035] Referring to FIG. 1 a lead frame 10 for use in an integrated circuit includes a plurality of leads 14, 16, at least two of which (and here, the two illustrated leads comprising the plurality of leads) include a respective die attach portion 24, 26 and connection portion 34, 36. The lead frame 10 has a first surface 10a and a second, opposing surface 10b (FIG. 2). As will be explained, the die attach portion 24, 26 of the leads (referred to herein sometimes as simply the die portion) can have a semiconductor die (FIG. 2) attached thereto.

[0036] The connection portion 34, 36 of the leads extends from a first end 34a, 36a proximate to the respective die portion 24, 26 to a second, distal end 34b, 36b distal from the die portion. Generally, the connection portion 34, 36 of the leads is elongated and is suitable for making electrical connection to electronic systems and components (not shown) outside of the integrated circuit package, such as a power source or microcontroller. For example, in the case of a through hole connection to a printed circuit board, the distal end 34b, 36b of the connection portions is provided in form of a pin suitable for a solder connection to a circuit board through hole. Alternatively, in the case of a surface mount connection, the distal end 34b, 36b of the connection portions will include a surface mount pad. Another embodiment may include a wire soldered or otherwise connected to the connection portions 34, 36.

[0037] The lead frame 10 has tie bars 46, 47, 48 that are provided to hold the leads 14, 16 together during manufacture. A first tie bar 46 is positioned near the die portion 24, 26 of the leads and the first end 34a, 36a of the connection portions and a second tie bar 48 is positioned near the distal end 34b, 36b of the connection portions 34, 36, as shown. Another tie bar portion is shown at 47 at the opposite side of the die portion 24, 26 from the lead ends 34a, 34b. In addition to facilitating manufacture, the tie bar(s) can also serve to protect the leads during handling, for example, by maintaining coplanarity of the elongated connection portions 34, 36.

[0038] An additional feature of the lead frame 10 includes extended regions 50 that extend beyond the distal ends 34b, 36b of the lead connection portions, as shown. These regions 50 may be molded with plastic to help maintain lead co-planarity with electrical isolation.

[0039] The connection portion 34, 36 of the leads 14, 16 may have widened regions 38 in order to further facilitate handling of the integrated circuit during assembly and improve the strength of the leads. The illustrative widened regions 38 extend slightly outward along a portion of the length of the connection portions in a direction away from the adjacent lead as shown, in order to maintain a desired spacing between the leads. It will be appreciated that the widened regions may have various shapes and dimensions to facilitate IC integrity during handling and assembly, or be eliminated in other embodiments, and may extend in a direction toward the adjacent lead(s) as long as the desired spacing between leads is achieved.

[0040] The lead frame 10 may be formed from various conventional materials and by various conventional techniques, such as stamping or etching. As one example, the lead frame 10 is a NiPdAu pre-plated lead frame. Other suitable materials for the lead frame include but are not limited to aluminum, copper, copper alloys, titanium, tungsten, chromium, Kovar™, nickel, or alloys of the metals. Furthermore, the lead and lead frame dimensions can be readily varied to suit particular application requirements. In one illustrative example, the leads 14, 16 have a thickness on the order of 0.25mm and the connection portions 34, 36 are on the order of 10mm long. Typically, the lead frame 10 which will be used to form a single integrated circuit, is formed (e.g., stamped) with a plurality of other identical or similar lead frames in a single stamping process for example, and the lead frames 10 separated during manufacture for formation of individual integrated circuits.

[0041] Referring also to FIG. 2, at a later stage of manufacture, a semiconductor die 40 can be attached to the lead frame 10. Thus, the lead frame 10 does not have a conventional contiguous die attach pad or area to which the die is attached, but rather the die is attached to die portions 24, 26 of at least two leads 14, 16 and thus to a non-contiguous surface. Accordingly, the lead frame 10 can be referred to as a "split lead frame" since there is not a contiguous die attach surface. The semiconductor die 40 has a first surface 40a in which a magnetic field sensing element 44 is disposed and a second, opposing surface 40b. The die 40 may be attached to the die attach portion 24, 26 of the leads such that the opposing die surface 40b is adjacent to the die attach portions 24, 26, in a die up arrangement. Alternatively, the semiconductor die 40 may be attached to the die attach portion 24, 26 of the leads such that the first, active die surface 40a is adjacent to the die attach portions 24, 26, in a flip-chip arrangement.

[0042] Various techniques and materials can be used to attach the die 44 to the die attach portions 24, 26. Since the die 44 is attached across multiple leads 14, 16, the mechanism 42 for attaching the die to the lead frame 10 must be a non-conductive adhesive 42, such as a non-conductive epoxy or tape, such as a Kapton® tape, or die attach film.

[0043] In addition to the magnetic field sensing element 44, the die 40 supports other electronic components and circuitry, and the sensing element 44 and other electronic components supported by the die can be coupled to the leads 14, 16 by various techniques, such as by solder balls, solder bumps, pillar bumps, or the illustrated wire bonds 52. If solder balls, solder bumps, or pillar bumps are used, the die 40 may be attached to the die attach portions 24, 26 with the active die surface 40a adjacent to the lead frame surface 10a, as in a flip-chip arrangement. In the illustrative embodiment of FIG. 2, the wire bonds are coupled between the die 40 and a location of the die attach portions 24, 26 distal from the respective connection portion 34, 36. While the lead frame 10 is shown to include two leads 14, 16, it will be appreciated by those of ordinary skill in the art that various numbers of leads, such as between two and eight, are possible.

[0044] While the illustrated die 40 is used to form a magnetic field sensor and thus, supports at least one magnetic field sensing element 44, it will be appreciated by those of ordinary skill in the art that the integrated circuit packaging described herein can be used in connection with other types of integrated circuits. As used herein, the term "magnetic field sensing element" is used to describe a variety of electronic elements that can sense a magnetic field. The magnetic field sensing element can be, but is not limited to, a Hall effect element, a magnetoresistance element, or a magnetotransistor. As is known, there are different types of Hall effect elements, for example, a planar Hall element, a vertical Hall element, and a Circular Vertical Hall (CVH) element. As is also known, there are different types of magnetoresistance elements, for example, a semiconductor magnetoresistance element such as Indium Antimonide (InSb), a giant magnetoresistance (GMR) element, an anisotropic magnetoresistance element (AMR), a tunneling magnetoresistance (TMR) element, and a magnetic tunnel junction (MTJ). The magnetic field sensing element may be a single element or, alternatively, may include two or more magnetic field sensing elements arranged in various configurations, e.g., a half bridge or full (Wheatstone) bridge. Depending on the device type and other application requirements, the magnetic field sensing element may be a device made of a type IV semiconductor material such as Silicon (Si) or Germanium (Ge), or a type III-V semiconductor material like Gallium-Arsenide (GaAs) or an Indium compound, e.g., Indium-Antimonide (InSb).

[0045] As is known, some of the above-described magnetic field sensing elements tend to have an axis of maximum sensitivity parallel to a substrate that supports the magnetic field sensing element, and others of the above-described magnetic field sensing elements tend to have an axis of maximum sensitivity perpendicular to a substrate that supports the magnetic field sensing element. In particular, planar Hall elements tend to have axes of sensitivity perpendicular to a substrate, while metal based or metallic magnetoresistance elements (e.g., GMR, TMR, AMR) and vertical Hall elements tend to have axes of sensitivity parallel to a substrate.

[0046] As used herein, the term "magnetic field sensor" is used to describe a circuit that uses a magnetic field sensing element, generally in combination with other circuits. Magnetic field sensors are used in a variety of applications, including, but not limited to, an angle sensor that senses an angle of a direction of a magnetic field, a current sensor that senses a magnetic field generated by a current carried by a current-carrying conductor, a magnetic switch that senses the proximity of a ferromagnetic object, a rotation detector that senses passing ferromagnetic articles, for example, magnetic domains of a ring magnet or a ferromagnetic target (e.g., gear teeth) where the magnetic field sensor is used in combination with a back-biased or other magnet, and a magnetic field sensor that senses a magnetic field density of a magnetic field.

[0047] The integrated circuit shown during manufacture in FIG. 2 includes at least one integrated passive component 60, such as a resistor, inductor, capacitor, or diode, and here includes a capacitor 60 attached to the lead frame 10. More particularly, the capacitor 60 is coupled across the die attach portion 24, 26 of respective leads 14, 16. The capacitor 60 may be useful to reduce EMC, ESD or address other electrical issues with the resulting sensor. For example, with capacitor 60, power to the sensor may be held longer in order to prevent a power on reset state by holding an output state in the case of a broken or damaged wire. It is possible to have other types of passive components coupled between leads and other numbers of capacitors, for example one capacitor may be provided between a power and ground or output and ground pins.

[0048] Various techniques and material are suitable for attaching the passive component 60 to the leads 14, 16. As one example, the capacitor is a surface mount capacitor and the die attach portions 24, 26 include respective surface mount pads, plated areas, or solder paste regions 28 to which the capacitor is attached, as shown. In general, the passive component 60 can be attached to the die attach portions 24, 26 by soldering or with a conductive adhesive, such as a conductive epoxy.

[0049] In some embodiments, the leads may have a cutout, depressed, or recessed region in which a passive component, such as capacitor 60, can be positioned below the surface 10a of the lead frame on which the die 40 is positioned. With such an arrangement, the "active area depth" of the sensor and the entire package thickness is advantageously reduced as compared to a package having a capacitor mounted on the lead frame surface 10a. In another embodiment the passive component 60 may be attached to the other side of the lead frame on surface 10b. Such an arrangement may allow further reduction of the active area depth by reducing the thickness of the mold material above the die. In other embodiments, a passive component may be attached to the opposing surface 10b of the lead frame 10. Additional aspects of integrated passive components are described in a U.S. Patent Application Publication No. US-2008-0013298-A1, entitled "Methods and Apparatus for Passive Attachment of Components for Integrated Circuits," which is assigned to the Assignee of the subject application.

[0050] Referring also to FIG. 3, a packaged integrated circuit magnetic field sensor 70 containing the lead frame 10 with leads 14, 16 and the subassembly of FIG. 2 is shown after overmolding. During overmolding, a non-conductive mold material 74 is provided to enclose the semiconductor die 40 and a portion of the leads 14, 16 including the die attach portions 24, 26.

[0051] The molded enclosure comprising a non-conductive mold material 74 may be formed by various techniques, including but not limited to injection molding, compression molding, transfer molding, and/or potting, from various non-conductive mold materials, such as Sumitomo FGT700. In general, the non-conductive mold material 74 is comprised of a non-conductive material so as to electrically isolate and mechanically protect the die 40 and the enclosed portion of the lead frame 10. Suitable materials for the non-conductive mold material 74 include thermoset and thermoplastic mold compounds and other commercially available IC mold compounds. It will be appreciated that the non-conductive mold material 74, while typically non-ferromagnetic, can contain a ferromagnetic material, such as in the form of ferromagnetic particles, as long as such material is sufficiently non-conductive.

[0052] A non-conductive mold material 78 is provided to enclose a distal end of the lead frame 10, beyond the extended regions 50 and the connection portion ends 34b, 36b, in order to provide a carrier that can be used to hold the integrated circuit 70 during handling and assembly and also to help maintain coplanarity of the leads. It will be appreciated by those of ordinary skill in the art that the second enclosure 78 may be removed prior to connecting the integrated circuit 70 to a printed circuit board for example. The tie bars 46, 48 are removed during manufacture in a process sometimes referred to as "singulation" in order to prevent shorting of the leads and to thereby provide the packaged magnetic field sensor integrated circuit 70 shown in FIG. 3.

[0053] Referring also to FIG. 4, the leads 14, 16 may be bent as shown, depending on the orientation of the system (e.g., circuit board) to which the IC 70 is being connected and the desired orientation of the magnetic field sensing element 44 relative to external targets being sensed. Notably, the diameter "d" (as defined by a circle enclosing the non-conductive mold material 74) is small, such as on the order of 6.0mm to 6.5mm in one illustrative embodiment and more generally between approximately 5.0mm and 7.0mm. This small volume/diameter package is attributable at least in part to the split lead frame design. In other words, because the die 40 is attached across die attach portions 24, 26 of multiple leads, a contiguous, generally larger area dedicated for attachment of the die is not required. The described package system includes one or more passive components, such as capacitor 60, which may form a passive network to reduce the overall size of a sensor system when compared to a package that requires an external attachment of the passive network that typically would occur on a PC board.

[0054] Referring also to FIG. 5, an alternative lead frame 100 for use in an integrated circuit includes a plurality of leads 114, 116, and 118, at least two of which (and here, all three of which) include a respective die attach portion 124, 126, 128 and a connection portion 134, 136, 138. The lead frame 100 has a first surface 100a and a second, opposing surface 100b (FIG. 6). As will be explained, the die attach portion 124, 126, 128 of the leads can have a semiconductor die (FIG. 6) attached thereto.

[0055] The connection portion 134, 136, 138 of the leads can be the same as or similar to the connection portion 34, 36 of the leads 14, 16 of FIG. 1 and extends from a first end 134a, 136a, 138a proximate to the respective die portion 124, 126, 128 to a second, distal end 134b, 136b, 138b distal from the die portion. Here again, the connection portion 134, 136, 138 of the leads is generally elongated and is suitable for electrical connection to electronic components or systems (not shown) outside of the integrated circuit package, such as by soldering to a printed circuit board. The connection portions may have wider regions as shown by 38 in Fig. 1 in the connection portions 134, 136, and 138.

[0056] The lead frame 100 has tie bars 146, 147, 148 that may be the same as or similar to tie bars 46, 48 of FIG. 1 and that are provided to hold the leads 114, 116, 118 together during manufacture. Here again, a first tie bar 146 is positioned near the die attach portion 124, 126, 128 of the leads and the first end 134a, 136a, 138a of the connection portions and a second tie bar 148 is positioned near the distal end 134b, 136b, 138b of the connection portions 134, 136, 138 as shown. A tie bar portion is shown at 147 at the opposite side of the die portion 124, 126, and 128 from the lead ends 134a, 136b, and 138b. Extended regions 150 that are the same as or similar to extended regions 50 of FIG. 1 may be provided.

[0057] The lead frame materials and formation techniques may be the same as or similar to the lead frame 10 of FIG. 1. Thus, as one example, the lead frame 100 may be a stamped NiPdAu pre-plated lead frame.

[0058] Referring also to the lead frame 100 during a later stage of manufacture as shown in FIG. 6, a semiconductor die 140 having a first surface 140a in which a magnetic field sensing element 144 is disposed and a second, opposing surface 140b can be attached to the lead frame 100 in either a die-up or flip-chip arrangement. Thus, here again the lead frame 100 does not have a conventional contiguous die attach pad or area to which the die is attached, but rather the die is attached to die portions 124, 126, 128 of at least two leads 114, 116, 118, and in the illustrative embodiment of FIG. 6, is attached to the die portions of three leads. The die 144 may be attached to the die portions 124, 126, 128 with a non-conductive adhesive 142, such as an epoxy, tape, or a combination of epoxy and tape as examples.

[0059] Wire bonds, such as wire bonds 152 as shown, or other suitable electrical connection mechanisms, such as solder balls, solder bumps, or pillar bumps as examples, can be used to electrically connect the magnetic field sensing element 144 and other electronic components supported by the die 140 to the lead frame 100. If solder balls, solder bumps, or pillar bumps are used, the die 140 may be placed with the die surface 140a adjacent to the surface 110a of the lead frame 110, as in a flip-chip arrangement. In the illustrative embodiment of FIG. 6, the wire bonds 152 are coupled between the die 140 and a location of the die attach portions 124, 126, 128 proximal from the respective connection portion 134, 136, 138. Here again, while the illustrated die 140 supports a magnetic field sensing element 144, it will be appreciated by those of ordinary skill in the art that the integrated circuit packaging described herein can be used in connection with other types of integrated circuits or sensors. Furthermore, while the lead frame 100 is shown to include three leads 114, 116, 118, it will be appreciated by those of ordinary skill in the art that various numbers of leads, such as between two and eight, are possible.

[0060] The integrated circuit shown during manufacture in FIG. 6 includes at least one integrated passive component, such as a resistor, inductor, capacitor, or diode, and here includes two capacitors 160, 164 attached to the lead frame 100. More particularly, the capacitor 160 is coupled across leads 114 and 116 and capacitor 164 is coupled across leads 116 and 118. Capacitors 160, 164 may be the same as or similar to capacitor 60 of FIG. 2. In one illustrative example, capacitors 160, 164 are surface mount capacitor that are attached to surface mount pads, solder paste regions, or plated areas 130.

[0061] Referring also to FIG. 7, a packaged integrated circuit magnetic field sensor 170 containing the lead frame 100 with leads 114, 116, 118 and the subassembly of FIG. 6 is shown after overmolding. During overmolding, a non-conductive mold material 174 that may be the same as or similar to the non-conductive mold material 74 of FIG. 3 is provided to enclose the semiconductor die 140 and a portion of the leads 114, 116, 118 including the die attach portions 124, 126, 128. Here again, the non-conductive mold material 174 may be formed by various techniques such as injection molding, compression molding, transfer molding, and/or potting and from various non-conductive mold materials, such as Sumitomo FGT700.

[0062] A non-conductive mold material 178 is provided to enclose a distal end of the lead frame 100, beyond the extended regions 150 and the connection portion ends 134b, 136b, 138b in order to provide a carrier that can be used to hold the integrated circuit during handling and assembly and also to help maintain coplanarity of the leads. It will be appreciated by those of ordinary skill in the art that the second enclosure 178 may be removed prior to connecting the integrated circuit 170 to a printed circuit board for example. The tie bars 146, 148 are removed during manufacture in a process sometimes referred to as "singulation" in order to prevent shorting of the leads and to thereby provide the packaged magnetic field sensor integrated circuit 170 shown in FIG. 7.

[0063] While not shown in the view of FIG. 7, it will be appreciated that the leads 114, 116, 118 may be bent for assembly, for example in the manner shown in FIG. 3. The diameter of the molded enclosure 174 is advantageously small as compared to a conventional integrated circuit in which the die is attached to a dedicated, contiguous die attach area, as explained above in connection with FIG. 4. The described package system includes one or more passive components, such as capacitors 160 and 164, which may form a passive network to reduce the overall size of a sensor system when compared to a package that requires an external attachment of the passive network that typically would occur on a PC board which would generally result in a larger diameter of the sensor assembly.

[0064] Referring also to FIG. 8, an alternative lead frame 200 is shown in which like elements of FIG. 5 are labeled with like reference characters. The lead frame 200 differs from the lead frame 100 of FIG. 5 only in the addition of extended regions 204 extending laterally from the leads at a position along the length of the respective lead connection portion 134, 136, 138, as shown. The extended regions 204 facilitate additional features of the integrated circuit sensor; namely, permitting one or more passive components to be coupled between respective pairs of leads and also permitting one or more suppression devices to be provided in order to enhance the electromagnetic compatibility (EMC) of the sensor and to reduce electrostatic discharge (ESD).

[0065] Thus, lead frame 200 includes a plurality of leads 114', 116', and 118', at least two of which (and here, all three of which) include a respective die portion 124, 126, 128 and a connection portion 134', 136', 138'. The connection portion 134', 136', 138' extends from a first end 134a, 136a, 138a proximate to the respective die portion 124, 126, 128 to a second, distal end 134b, 136b, 138b distal from the die portion. The connection portion 134, 136, 138 of the leads is generally elongated and suitable for electrical connection to electronic components or systems (not shown) outside of the integrated circuit package, such as by soldering to a printed circuit board, and here includes extended regions 204.

[0066] Referring also to FIG. 9, in which like elements to FIG. 7 are labeled with like reference characters, an integrated circuit magnetic field sensor 210 differs from the sensor of FIG. 7 in that the sensor 210 contains lead frame 200 (FIG. 8). The sensor 210 includes a suppression device 230 is positioned to enclose a portion of one or more leads, here lead 114', at a location of the respective lead spaced from the non-conductive mold material 174. The suppression device 230 is provided in order to enhance the electromagnetic compatibility (EMC) of the sensor and to reduce electrostatic discharge (ESD). The suppression device 230 may be provided in various geometries (i.e., size and shape), and at various locations of the sensor, and may be fabricated by various techniques.

[0067] The suppression device 230 is comprised of a soft ferromagnetic material. In some embodiments, it may be desirable for the molded soft ferromagnetic element 230 to have a relatively low coercivity and high permeability. Suitable soft ferromagnetic materials include, but are not limited to permalloy, NiCo alloys, NiFe alloys, steel, nickel, and soft ferromagnetic ferrites. As described above for hard ferromagnetic materials, it may also be desirable to form a soft ferromagnetic suppression device in the presence of a magnetic field for a more anisotropic ferromagnetic material. In another embodiment it may be desirable to form an isotropic soft ferromagnetic suppression body without using a magnetic field applied during molding.

[0068] In other embodiments, the suppression device 230 may be formed by a molding process and is shown to enclose an extended portion 204 (FIG. 8). While lead 114' is shown in FIG. 8 to have an extended region 204, it will be appreciated that such extended region may not be necessary in the case of molded suppression device 230. Because of the placement of the suppression device on the leads, the mold material comprising the device must be of sufficient resistivity to prevent unwanted electrical signals from being passed between the leads.

[0069] The suppression device 230 comprises a ferromagnetic mold material and may be comprised of a hard or permanent magnetic material. In some embodiments, it may be desirable for the ferromagnetic mold material to have a coercivity larger than its remanence. Illustrative hard magnetic materials for the suppression device 230 include, but are not limited to hard magnetic ferrites, SmCo alloys, NdFeB alloy materials, or Plastiform® materials of Arnold Magnetic Technologies Corp., or other plastic compounds with hard magnetic particles, for example a thermoset polymer such as polyphenylene sulfide material (PPS) or nylon material containing SmCo, NdFeB, or hard ferromagnetic ferrite magnetic particles; or a thermoset polymer such as SUMIKON®EME of Sumitomo Bakelite Co., Ltd or similar type of thermoset mold material containing hard magnetic particles. In some embodiments it may be desirable to align the hard ferromagnetic particles during molding to form a more anisotropic or directional permanent magnetic material by molding in the presence of a magnetic field; whereas, in other embodiments, a sufficient magnet may result without an alignment step during molding for isotropic materials. It will be appreciated that a NdFeB or a SmCo alloy may contain other elements to improve temperature performance, magnetic coercivity, or other magnetic properties useful to a magnetic design.

[0070] The suppression device 230 extends from the connection portion of the lead 114' to surround the lead and thus, extends above and below the connection portion. While the device 230 is shown to extend above and below the lead by the approximately the same distance, it will be appreciated by those of ordinary skill in the art that this need not be the case. Generally, the overall height of the suppression device 230 may be (but is not required to be) less than the overall height of the mold enclosure 174 so as not extend beyond the main package body.

[0071] The suppression device may comprise a plurality of individual molded ferromagnetic devices, each enclosing a portion of a respective lead 114', 116' and 118'. Alternatively or additionally, the suppression device may be provided in the form of a shared molded device formed to enclose a portion of more than one lead. In some embodiments, the molded suppression device 230 may include a first mold element in contact with the lead and a second mold element enclosing at least a portion of the first mold element.

[0072] According to a further feature, the magnetic field sensor integrated circuit 210 includes a passive component 240. As is known and described in U.S. Patent Application Publication No. US-2012-0086090-A1, it is sometimes desirable to integrate one or more passive components, such as capacitors, resistors, inductors, or diodes on an integrated circuit lead frame for filtering and/or other functionality. The passive component 240, such as a capacitor, may be fabricated by techniques described in the above-referenced U.S. Patent Application Publication No. US-2012-0086090-A1.

[0073] The extended regions 204 of the leads 116', 118' to facilitate attachment of the passive component 240 therebetween, such as by soldering. Alternatively, the extended regions 204 may be omitted and the passive component(s) may be coupled directly across respective pairs of leads.

[0074] The passive component 240 can be enclosed by a mold material to provide a mold enclosure 244. The mold enclosure 244 can comprise a non-conductive mold material, that can be similar to or the same as the material comprising the mold enclosure 174. Alternatively, the passive component 240 can be enclosed by a ferromagnetic material that may be the same as or similar to the ferromagnetic material comprising suppression device 230 for example in order to thereby provide a further suppression device provided the ferromagnetic material is sufficiently non-conductive.

[0075] The mold enclosure 244 is sized and shaped to enclose the passive component 240 and meet other packaging size requirements. It will be appreciated by those of ordinary skill in the art that other variations are possible for providing a passive component across leads and/or for providing a suppression device. For example, a ferromagnetic bead may be enclosed by a molded suppression device 230 comprising a non-ferromagnetic mold material.

[0076] In some embodiments in which the lead frame includes more than two leads, it may be desirable to have one or more leads be no connect leads provided for purposes of passive component attachment. For example, in the embodiment of FIG. 9, it may be desirable to have the middle lead 116' be a no connect lead in which case the lead 116' could be trimmed near the enclosure 244 (as shown by the dotted lines of lead 116' in FIG. 9 that illustrates the lead portion that would be removed in such an embodiment). Such a trimmed embodiment would result in two usable leads 114' and 118' for two-wire sensor applications, although it will be appreciated that other number of leads using similar no connect lead techniques are possible. In one such an embodiment, the passive component 164 (FIG. 6) could be a resistor, the passive component 160 could be a capacitor, and the passive component 240 could be a capacitor, thereby providing a different passive network without increasing the package diameter. In other embodiments different combinations of resistors, inductors, capacitors, or diodes (including zener diodes) may be utilized.

[0077] Referring also to FIG. 10, an alternative packaged magnetic field sensor integrated circuit 250 includes a semiconductor die 252, a magnetic field sensing element 262, and a split lead frame 254. The split lead frame 254 includes leads 266, 268, and 270, at least two of which (and here all three of which) include a respective die attach portion 272, 274, 276 and connection portion 292, 294, 296 (only partially shown in the view of FIG. 10).

[0078] Here, the die 252 is attached to the top of the lead frame 254 and more particularly is attached to die attach portions 266, 268, 270, with a non-conductive adhesive, such as an epoxy or tape. The leads 266, 268, 270 are electrically coupled to the die 252 by wire bonds 280, as shown. However, other electrical connecting mechanisms, such as solder balls, solder bumps, and pillar bumps, may be suitable in embodiments in which the die 252 is mounted with its active surface (in which the magnetic field sensing element 262 is disposed) adjacent to the lead frame as described above in a flip-chip type of arrangement.

[0079] The connection portion 292, 294, 296 of the leads extends from a first end proximate to the respective die portion 266, 268, 270 to a second, distal end (not shown) distal from the die portion. Generally, the connection portion 292, 294, 296 of the leads is elongated and is suitable for electrical connection to electronic components or systems (not shown) outside of the integrated circuit package, such as by soldering to a printed circuit board.

[0080] The sensor 250 further includes at least one integrated passive component, and here two such components in the form of capacitors 264a, 264b, attached across respective pairs of die attach portions 272, 274 and 274, 276. The capacitors 264a, 264b may be the same as or similar to capacitor 60 of FIG. 2.

[0081] The integrated circuit 250 further includes a passive component coupled in series, or "in-line" with at least one lead. To this end, a lead die attach portion 272 includes at least two separate portions 272a and 272b and the portions are coupled together through one or more passive components 260. More particularly, each of the lead die attach portions 272a and 272b has an end that is spaced from and proximate to the end of the other lead portion. Passive component 260 is coupled to both the lead portion 272a and to lead portion 272b, thereby being electrically connected in series with the lead. This arrangement can advantageously permit series coupling of passive components with one or more leads.

[0082] The passive component 260 may take various forms, such as a resistor, capacitor, inductor, or diode as examples, which component(s) is provided for various purposes, such as to improve EMC performance. In one embodiment, the passive component 260 is a resistor. It will be appreciated that in embodiments in which the passive component 260 is a capacitor, AC voltages can be applied. Also, it will be appreciated that while only one lead is shown to have an in-line passive component 260, the same or a different type of passive component can be similarly coupled in-line with more than one lead. Also, a single lead die attach portion, such as that formed by lead portions 272a and 272b, can have more than one break and more than one passive component coupled across the respective breaks so as to form an arrangement in which more than one passive component is coupled in series with a respective lead.

[0083] The lead frame 254 contains one or more slots, and here two slots 254a and 254b. As is well known in the art, in the presence of a changing, AC or transient magnetic field (e.g., a magnetic field surrounding a current carrying conductor), eddy currents can be induced in the conductive lead frame 254. The presence of the slots can move the position of the eddy currents and also influence the eddy currents to result in a smaller magnetic field error so that a Hall effect element experiences a smaller magnetic field from the eddy currents than it would otherwise experience, resulting in less error in the measured field. Furthermore, if the magnetic field associated with the eddy current is not uniform or symmetrical about the Hall effect element, the Hall effect element might generate an undesirable offset voltage.

[0084] Lead frame slots 254a, 254b tend to reduce a size (e.g., a diameter or path length) of the closed loops and the position of the loops with respect to the sensing element(s) in which the eddy currents travel in the lead frame 254. It will be understood that the reduced size of the closed loops in which the eddy currents travel results in smaller eddy currents for a smaller local affect on the changing magnetic field that induced the eddy current. Therefore, the measured magnetic field of a sensor having a Hall effect 262 element is less affected by eddy currents due to the slots 254a, 254b.

[0085] Instead of an eddy current rotating about the Hall effect element 262, the slot(s) 254a, 254b result in eddy currents to each side of the Hall element. While the magnetic fields resulting from the eddy currents are additive, the overall magnitude field strength, compared to a single eddy current with no slot, is lower due to the increased distance of the eddy currents to the sensing element(s).

[0086] It is understood that any number of slots can be formed in a wide variety of configurations to meet the needs of a particular application. In the illustrative embodiment of FIG. 10, slots 254a, 254b are formed in the die attach portion 274 of lead 268, however, it will be appreciated by those of ordinary skill in the art that other numbers and arrangements of slots are possible. The slots reduce the eddy current flows and enhance the overall performance of the sensor.

[0087] It is understood that the term slot should be broadly construed to cover generally interruptions in the conductivity of the lead frame. For example, slots can include a few relatively large holes as well as smaller holes in a relatively high density. In addition, the term slot is not intended to refer to any particular geometry. For example, slot includes a wide variety of regular and irregular shapes, such as tapers, ovals, etc. Further, it is understood that the direction of the slot(s) can vary. Also, it will be apparent that it may be desirable to position the slot(s) based upon the type of sensor.

[0088] Additional details of the slotted lead frame may be found in U.S. Patent Application Publication No. US-2012-0086090-A1 for example, which application is assigned to the assignee of the subject invention and incorporated herein by reference in its entirety.

[0089] The integrated circuit 250 further includes a non-conductive mold material 256. The non-conductive mold material 256 encloses the die 252, at least a portion of the lead frame 254, and the capacitors 264a, 264b. Optionally, the integrated circuit 250 may further include a ferromagnetic mold material 258. And the sensor may include a third, overmold material, not shown here.

[0090] In use, the magnetic field sensor 250 may be positioned in proximity to a moveable magnetically permeable ferromagnetic article, or target (not shown), such that the magnetic field transducer 262 is adjacent to the article and is thereby exposed to a magnetic field altered by movement of the article. The magnetic field transducer 262 generates a magnetic field signal proportional to the magnetic field. The ferromagnetic article may be comprised of a hard ferromagnetic, or simply hard magnetic material (i.e., a permanent magnet such as a segmented ring magnet), a soft ferromagnetic material, or even an electromagnet and embodiments described herein may be used in conjunction with any such article arrangement.

[0091] In embodiments in which the article is comprised of a soft ferromagnetic material, the ferromagnetic mold material 258 is comprised of a hard ferromagnetic material to form a bias magnet; whereas in embodiments in which the article is comprised of a hard ferromagnetic material, the ferromagnetic mold material 258 may be soft ferromagnetic material to form a concentrator, or a hard magnetic material where a bias field is desired (for example, in the case of a magnetoresistance element that is biased with a hard magnetic material or permanent magnet). In embodiments in which the ferromagnetic mold material 258 comprises a hard ferromagnetic material to form a bias magnet and in which the sensor 250 is oriented relative to the target such that transducer 262 is closer to the target than the ferromagnetic mold material 258 as shown, the bias magnet may be referred to as a back bias magnet.

[0092] The non-conductive mold material 256 is comprised of a non-conductive material so as to electrically isolate and mechanically protect the die 252 and the enclosed portion of the lead frame 254. Suitable materials for the non-conductive mold material 256 include thermoset and thermoplastic mold compounds and other commercially available IC mold compounds. It will be appreciated that the non-conductive mold material 256 can contain a ferromagnetic material, such as in the form of ferromagnetic particles, as long as such material is sufficiently non-conductive.

[0093] The non-conductive mold material 256 is applied to the lead frame/die subassembly, such as in a first molding step, to enclose the die 252 and a portion of the lead frame 254. The shape and dimensions of the non-conductive mold material are selected to suit particular IC package requirements.

[0094] In some embodiments as noted above, the ferromagnetic mold material 258 is comprised of a hard or permanent magnetic material to form a bias magnet. As will be apparent to those of ordinary skill in the art, various materials are suitable for providing the ferromagnetic mold material 258 depending on the operating temperature range and final package size. In some embodiments, it may be desirable for the ferromagnetic mold material to have a coercivity larger than its remanence.

[0095] Illustrative hard magnetic materials for the ferromagnetic mold material include, but are not limited to hard magnetic ferrites, SmCo alloys, NdFeB alloy materials, or Plastiform® materials of Arnold Magnetic Technologies Corp., or other plastic compounds with hard magnetic particles, for example a thermoset polymer such as polyphenylene sulfide material (PPS) or nylon material containing SmCo, NdFeB, or hard ferromagnetic ferrite magnetic particles; or a thermoset polymer such as SUMIKON®EME of Sumitomo Bakelite Co., Ltd or similar type of thermoset mold material containing hard magnetic particles. In some embodiments it may be desirable to align the hard ferromagnetic particles during molding to form a more anisotropic or directional permanent magnetic material by molding in the presence of a magnetic field; whereas, in other embodiments, a sufficient magnet may result without an alignment step during molding for isotropic materials. It will be appreciated that a NdFeB or a SmCo alloy may contain other elements to improve temperature performance, magnetic coercivity, or other magnetic properties useful to a magnetic design.

[0096] In other embodiments, the ferromagnetic mold material 258 is comprised of a soft ferromagnetic material to form a concentrator. As will be apparent to those of ordinary skill in the art, various materials are suitable for providing the ferromagnetic mold material 258 in the form of a soft ferromagnetic material. In some embodiments, it may be desirable for the soft ferromagnetic mold material to have a relatively low coercivity and high permeability. Suitable soft ferromagnetic materials include, but are not limited to permalloy, NiCo alloys, NiFe alloys, steel, nickel, and soft ferromagnetic ferrites.

[0097] The ferromagnetic mold material 258 is secured to the non-conductive mold material 256, such as in a molding step or with an adhesive, such as a thermoset adhesive (e.g., a two part epoxy).

[0098] In some embodiments, a portion of the non-conductive mold material 256 that contacts the ferromagnetic mold material 258 and/or the portion of the ferromagnetic mold material that contacts the non-conductive mold material has a securing mechanism in order to improve the adhesion between the two materials and to prevent or reduce lateral slippage or shear between the materials. As one example, overhanging portions 286 of the lead frame that extend beyond the non-conductive mold material 256, serve to enhance adhesion of the non-conductive mold material 256 to the ferromagnetic mold material 258 and the lead frame. Because the overhanging portions 286 of the lead frame extend into the ferromagnetic mold material, it will be appreciated that the ferromagnetic mold material should be non-conductive or have a sufficiently low conductivity to prevent the leads from electrically shorting resulting in the device not operating as intended. Slots 284 in the lead frame 254 also serve to enhance adhesion of the non-conductive mold material 256 to the lead frame 254.

[0099] It will be appreciated by those of ordinary skill in the art, that various types of processes may be used to form the mold materials including but not limited to molding, such as compression molding, injection molding, and transfer molding, and potting. Furthermore, combinations of the various techniques for forming the mold materials are possible.

[00100] A mold cavity used to define the ferromagnetic mold material 258 may include a mandrel so that the ferromagnetic mold material forms a ring-shaped structure having a central aperture. The mold material 258 may form a conventional O-shaped ring structure or a D-shaped structure. Alternatively, the ferromagnetic mold material 258 may form only a partial ring-like structure, as may be described as a "C" or "U" shaped structure. More generally, the ferromagnetic mold material 258 may comprise a non-contiguous central region such that the central region is not formed integrally with its outer region. Such central region may be an open area, may contain a ferromagnetic material, or a separately formed element such as a steel rod for example.

[00101] Additional features of the mold materials 256, 258 are possible. For example, the non-conductive mold material 256 may include a protrusion extending into a portion of the ferromagnetic mold material 258 and certain tapers may be provided to the ferromagnetic mold material.

[00102] Referring to FIG. 11, a further alternative lead frame 310 for use in an integrated circuit includes a plurality of leads 314, 316, at least two of which (and here, the two illustrated leads comprising the plurality of leads) include a respective die attach portion 324, 326 and connection portion 334, 336. The lead frame 310 has a first surface

310a and a second, opposing surface 310b (FIG. 11A). As will be explained, the die attach portion 324, 326 of the leads (referred to herein sometimes as simply the die portion) can have a semiconductor die 340 (FIGs. 11A and 11B) attached thereto underneath the leads adjacent to th second surface 310b of the lead frame 310. This type of die mounting is sometimes referred to as "Lead on Chip".

[000103] The die attach portions 324 and 326 may have reduced area (as indicated generally by arrows 374) when compared to the die attach portions 24, 26 of FIG. 1 which can facilitate coupling the die to the leads as will be described. Other features of the lead frame 310 are similar to or the same as like features of previously described lead frames.

[000104] The connection portion 334, 336 of the leads extends from a first end 334a, 336a proximate to the respective die portion 324, 326 to a second, distal end 334b, 336b distal from the die portion. Generally, the connection portion 334, 336 of the leads is elongated and is suitable for making electrical connection to electronic systems and components (not shown) outside of the integrated circuit package, such as a power source or microcontroller. For example, in the case of a through hole connection to a printed circuit board, the distal end 334b, 336b of the connection portions is provided in form of a pin suitable for a solder connection to a circuit board through hole. Alternatively, in the case of a surface mount connection, the distal end 334b, 336b of the connection portions will include a surface mount pad. Another embodiment may include a wire soldered or otherwise connected to the connection portions 334, 336.

[0105] The lead frame 310 has tie bars 346, 347, 348 that are provided to hold the leads 314, 316 together during manufacture. A first tie bar 346 is positioned near the die portion 324, 326 of the leads and the first end 334a, 336a of the connection portions and a second tie bar 348 is positioned near the distal end 334b, 336b of the connection portions 334, 336, as shown. Another tie bar portion 347 is shown at the opposite end of the die portion 324, 326 from the lead ends 334a, 334b. In addition to facilitating manufacture, the tie bar(s) can also serve to protect the leads during handling, for example, by maintaining coplanarity of the elongated connection portions 334, 336.

[0106] An additional feature of the lead frame 310 includes extended regions 350 that extend beyond the distal ends 334b, 336b of the lead connection portions, as shown. These regions 350 may be molded with plastic to help maintain lead co-planarity with electrical isolation.

[0107] The connection portion 334, 336 of the leads 314, 316 may have widened regions 338 in order to further facilitate handling of the integrated circuit during assembly and improve the strength of the leads. The illustrative widened regions 338 extend slightly outward along a portion of the length of the connection portions in a direction away from the adjacent lead as shown, in order to maintain a desired spacing between the leads. It will be appreciated that the widened regions may have various shapes and dimensions to facilitate IC integrity during handling and assembly, or be eliminated in other embodiments, and may extend in a direction toward the adjacent lead(s) as long as the desired spacing between leads is achieved.

[0108] The lead frame 310 may be formed from various conventional materials and by various conventional techniques, such as stamping or etching. As one example, the lead frame 310 is a NiPdAu pre-plated lead frame. Other suitable materials for the lead frame include but are not limited to aluminum, copper, copper alloys, titanium, tungsten, chromium, Kovar™, nickel, or alloys of the metals. Furthermore, the lead and lead frame dimensions can be readily varied to suit particular application requirements. In one illustrative example, the leads 314, 316 have a thickness on the order of 0.25mm and the connection portions 334, 336 are on the order of 10mm long. Typically, the lead frame 310 which will be used to form a single integrated circuit, is formed (e.g., stamped) with a plurality of other identical or similar lead frames in a single stamping process for example, and the lead frames 310 separated during manufacture for formation of individual integrated circuits.

[0109] Referring also to the lead frame 310 during a later stage of manufacture as shown in FIG. 11A and the cross-sectional view of FIG. 11B taken along line A-A of FIG. 11A, the semiconductor die 340 has a first surface 340a in which a magnetic field sensing element 344 is disposed and a second, opposing surface 340b. The die 340 can be attached to the lead frame 310, here in a lead on chip arrangement, with the die surface

340a adjacent to the surface 310b of the lead frame 310. Here again, the lead frame 310 does not have a conventional contiguous die attach pad or area to which the die is attached, but rather the die is attached to die portions 324, 326 of leads 314, 316.

[0110] In the illustrated embodiment, the semiconductor die 340 extends beyond the lead frame die attach portions 324, 326. In other embodiments, the die 340 may be more closely aligned to the edges of the lead frame die portions 324, 326. And in further alternative embodiments, the die 340 may be attached to the die attach portions 324, 326, but not extend past or even to the edges of the die portions 324, 326.

[0111] The die 340 may be attached to the die portions 324, 326 with a respective non-conductive adhesive 330, 332, such as a Kapton® tape, or die attach film, or other suitable attachment means. It may be desirable to have the non-conductive adhesive, tape, or film 330, 332 extend beyond the edges of the lead frame die portions 324, 326, as shown, in order to ensure sufficient electrical isolation between the die 340 and lead frame 310. It will be appreciated that while the non-conductive adhesive is shown to be provided in the form of two separate pieces, a single adhesive element may be used.

[0112] Wire bonds, such as wire bonds 352 as shown, or other suitable electrical connection mechanisms, can be used to electrically connect the magnetic field sensing element 344 and other electronic components supported by the die 340 to the lead frame 310. In the illustrative wire bond embodiment, bond pads 370 and 372 on the die 340 may be provided between the die portions 324, 326, as shown.

[0113] The die attach portions 324, 326 are configured (i.e., sized, shaped, and located relative to each other) so as to expose a portion of the die surface 340a in order to facilitate wire bonding. For example, in the illustrative embodiment, the die attach portions 324, 326 can be considered to have a reduced area as compared to die attach portions 24, 26 of FIG. 1 (as indicated generally by arrows 374, FIG. 11) which forms an L-shape. By providing the die attach portions with this reduced area and using the described lead on chip arrangement, the wire bonds can be located within the perimeter of the die, thereby allowing for a larger die size to fit in the same IC package than may otherwise be possible with chip on lead technology.

[0114] An optional passive component 360 may be coupled to the lead frame 310. The capacitor 360 is coupled across leads 314, 316 and may be the same as or similar to capacitor 60 of FIG. 2. In one embodiment, passive component 360 is a capacitor, while in other embodiments the passive component 360 may be an inductor, a resistor, a diode, a zener diode, die with a passive network (for example an RLC network on a die), or other component. Other combinations of passive components may also be used in conjunction with the lead on chip lead frame 310. The capacitor 360 may be a surface mount capacitor attached to surface mount pads, solder paste regions, or plated areas 328, such as by soldering or with a conductive adhesive, such as a conductive epoxy. In other embodiments the passive component may be in die form and wire bonds may be used to attach the passive component to the leads 314, 316 in die attach portions 324, 326.

[0115] In the case where a passive component 360 is provided, the use of a lead on chip configuration allows the die 340 to extend under the passive component when the passive component is attached to the first surface 310a of the lead frame 310. This arrangement results in a larger allowable die for the same size overmold package, as contrasted to embodiments in which the die and passive components are attached to the same surface of the lead frame.

[0116] The lead frame subassembly shown in FIG. 11A may be overmolded to enclose the semiconductor die 340 and portions of the leads 314, 316 including the die attach portions 324, 326 as described above in relation to previous embodiments. In one embodiment, the overmold will be with a non-conductive material. In other embodiments a second overmold material which may be a soft ferromagnetic, or hard ferromagnetic mold material may be provided. Once overmolded, the lead frame subassembly of FIGs. 11, 11A, and 11B will resemble the packaged integrated circuit magnetic field sensor 70 of FIG. 3 and may be formed by the same or similar techniques with the same or similar materials.

[0117] Although FIG. 11 only shows two leads 314, 316, other numbers of leads are also possible, for example including but not limited to between two and eight leads. Passive components may be placed between the leads or in series with the same lead as described in connection with other embodiments above.

[0118] Having described preferred embodiments of the invention it will now become apparent to those of ordinary skill in the art that other embodiments incorporating these concepts may be used.

[0119] For example, it will be appreciated by those of ordinary skill in the art that the package types, shapes, and dimensions, including but not limited to the thicknesses of the mold materials, can be readily varied to suit a particular application both in terms of the electrical and magnetic requirements as well as any packaging considerations. It will also be appreciated that the various features shown and described herein in connection with the various embodiments can be selectively combined.

[0120] Accordingly, it is submitted that that the invention should not be limited to the described embodiments but rather should be limited only by the spirit and scope of the appended claims. All publications and references cited herein are expressly incorporated herein by reference in their entirety.

[0121] What is claimed is:

CLAIMS

1. A magnetic field sensor comprising:

a lead frame having a first surface, a second opposing surface, and comprising a plurality of leads, wherein at least two of the plurality of leads have a connection portion and a die attach portion; and

a semiconductor die supporting a magnetic field sensing element and attached to the die attach portion of the at least two leads.

2. The magnetic field sensor of claim 1 further comprising a non-conductive mold material enclosing the semiconductor die and the die attach portion of the at least two leads.

3. The magnetic field sensor of claim 1 further comprising a passive component coupled to at least two of the plurality of leads.

4. The magnetic field sensor of claim 3 wherein the passive component is a capacitor.

5. The magnetic field sensor of claim 3 wherein the passive component is coupled to the die attach portion of the at least two leads.

6. The magnetic field sensor of claim 5 further comprising at least two passive components, each coupled between a respective pair of die attach portions.

7. The magnetic field sensor of claim 3 wherein the passive component is coupled to the connection portion of the at least two leads.

8. The magnetic field sensor of claim 1 wherein the connection portion of at least one of the at least two leads has a widened portion extending away from another one of the at least two leads.

9. The magnetic field sensor of claim 1 further comprising a wire bond coupled between the semiconductor die and a location of the die attach portion of at least one of the at least two leads distal from the connection portion of the at least one lead.

10. The magnetic field sensor of claim 1 further comprising a wire bond coupled between the semiconductor die and a location of the die attach portion of at least one of the at least two leads proximate to the connection portion of the at least one lead.

11. The magnetic field sensor of claim 1 wherein at least one of the plurality of leads has a first portion that is separated from a second portion of the lead and wherein the magnetic field sensor further comprises a passive component coupled between the first portion and second portion of the at least one lead.

12. The magnetic field sensor of claim 11 wherein the passive component is a resistor.

13. The magnetic field sensor of claim 1 wherein the die attach portion of at least one of the at least two leads comprises at least one slot.

14. The magnetic field sensor of claim 1 further comprising a non-conductive adhesive between the semiconductor die and the die attach portion of the at least two leads.

15. The magnetic field sensor of claim 2 further comprising a ferromagnetic mold material secured to a portion of the non-conductive mold material.

16. The magnetic field sensor of claim 1 further comprising a ferromagnetic mold material secured to the connection portion of at least one of the plurality of leads.

17. The magnetic field sensor of claim 1 further comprising a ferromagnetic bead secured to the connection portion of at least one of the plurality of leads.

18. The magnetic field sensor of claim 1 wherein the semiconductor die has a first surface in which the magnetic field sensing element is disposed and a second, opposing surface and wherein the second, opposing surface is attached to the die attach portion of the at least two leads.

19. The magnetic field sensor of claim 1 wherein the semiconductor die has a first surface in which the magnetic field sensing element is disposed and a second, opposing surface and wherein the first surface is attached to the die attach portion of the at least two leads.

20. A magnetic field sensor comprising:

a lead frame having a first surface, a second opposing surface, and comprising a plurality of leads, wherein at least two of the plurality of leads have a connection portion and a die attach portion;

a semiconductor die supporting a magnetic field sensing element and attached to the die attach portion of the at least two leads;

a passive component coupled to at least two of the plurality of leads; and

a non-conductive mold material enclosing the semiconductor die and the die attach portion of the at least two leads, wherein the non-conductive mold material has a diameter of less than approximately 7.0mm.

21. The magnetic field sensor of claim 20 wherein the passive component is a capacitor.

22. The magnetic field sensor of claim 21 wherein the capacitor is coupled to the die attach portion of the at least two leads.

23. A magnetic field sensor comprising:

a lead frame having a first surface, a second opposing surface, and comprising a plurality of leads, wherein at least two of the plurality of leads have a connection portion and a die attach portion;

a semiconductor die supporting a magnetic field sensing element and attached to the die attach portion of the at least two leads; and at least one wire bond coupled between the die and the first surface of the lead frame, wherein the die is attached to the second surface of the lead frame.

24. The magnetic field sensor of claim 23 wherein the die attach portion of the at least two leads is configured to expose a portion of the die to which the at least one wire bond is coupled.

25. The magnetic field sensor of claim 24 wherein the die comprises at least two bond pads disposed between and exposed by configuration of the die attach portion of the at least two leads.

26. The magnetic field sensor of claim 23 further comprising a non-conductive mold material enclosing the semiconductor die and the die attach portion of the at least two leads.

27. The magnetic field sensor of claim 23 further comprising a passive component coupled to at least two of the plurality of leads.

28. The magnetic field sensor of claim 26 wherein the passive component is a capacitor.

29. The magnetic field sensor of claim 26 wherein the passive component is coupled to the die attach portion of the at least two leads.

30. The magnetic field sensor of claim 29 further comprising at least two passive components, each coupled between a respective pair of die attach portions.

31. The magnetic field sensor of claim 27 wherein the passive component is coupled to the connection portion of the at least two leads.

32. The magnetic field sensor of claim 23 further comprising a non-conductive adhesive or tape between the semiconductor die and the die attach portion of the at least two leads.

33. The magnetic field sensor of claim 26 further comprising a ferromagnetic mold material secured to a portion of the non-conductive mold material.

34. The magnetic field sensor of claim 23 further comprising a ferromagnetic mold material secured to the connection portion of at least one of the plurality of leads.

35. A magnetic field sensor comprising:

a lead frame having a first surface, a second opposing surface, and comprising a plurality of leads, wherein at least two of the plurality of leads have a connection portion and a die attach portion;

a semiconductor die supporting a magnetic field sensing element and attached to the die attach portion of the at least two leads;

at least one wire bond coupled between the die and the first surface of the lead frame, wherein the die is attached to the second surface of the lead frame;

a passive component coupled to at least two of the plurality of leads; and

a non-conductive mold material enclosing the semiconductor die and the die attach portion of the at least two leads, wherein the non-conductive mold material has a diameter of less than approximately 7.0mm.

36. The magnetic field sensor of claim 35 wherein the passive component is a capacitor.

37. The magnetic field sensor of claim 36 wherein the capacitor is coupled to the die attach portion of the at least two leads.

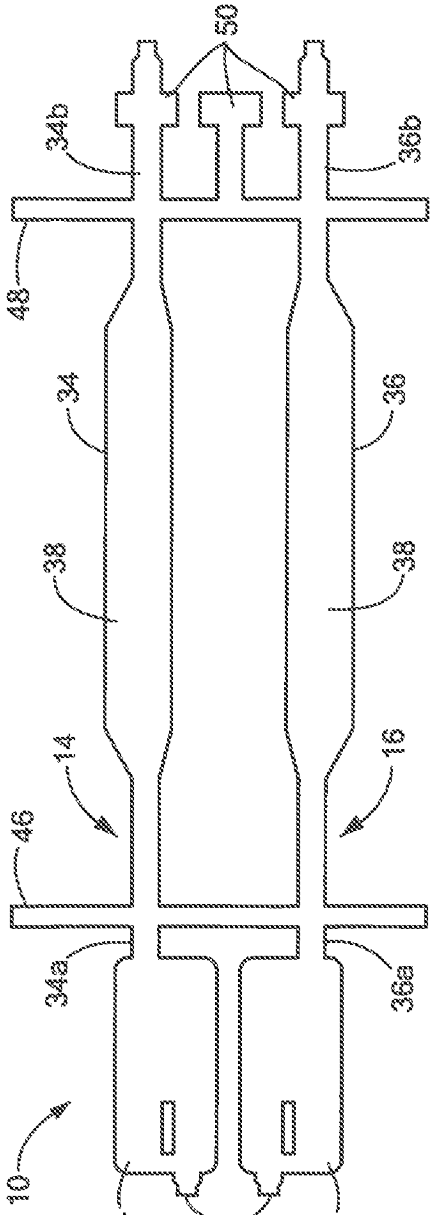
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FIG. 1

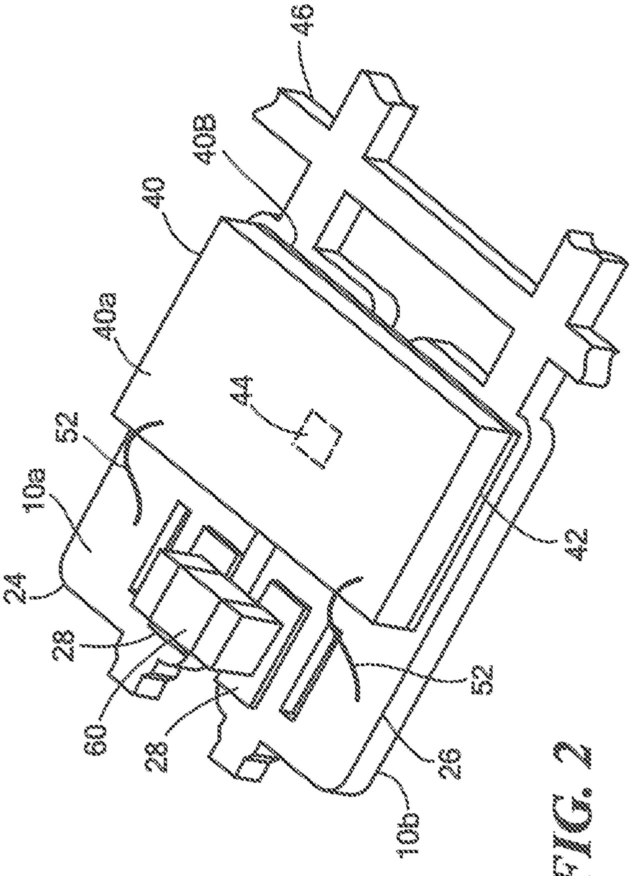
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FIG. 2

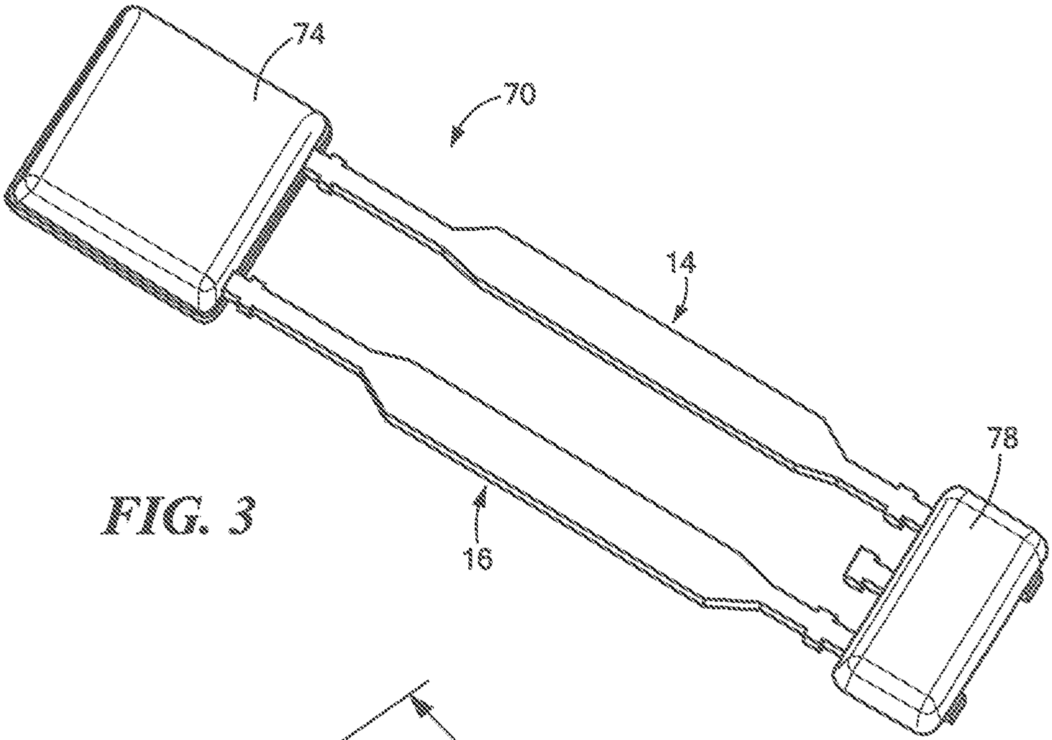

FIG. 3

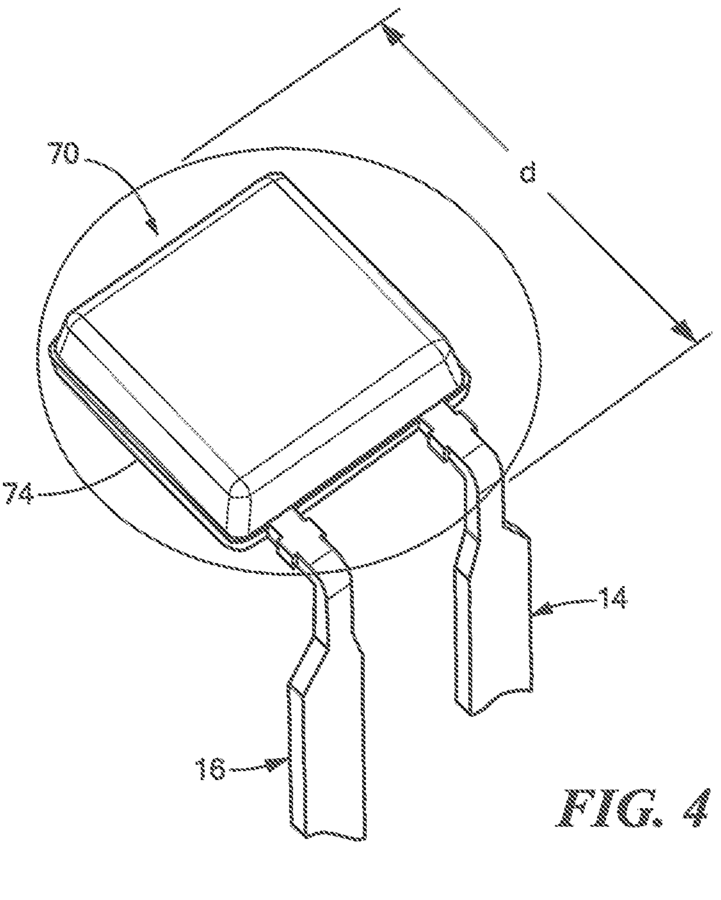

FIG. 4

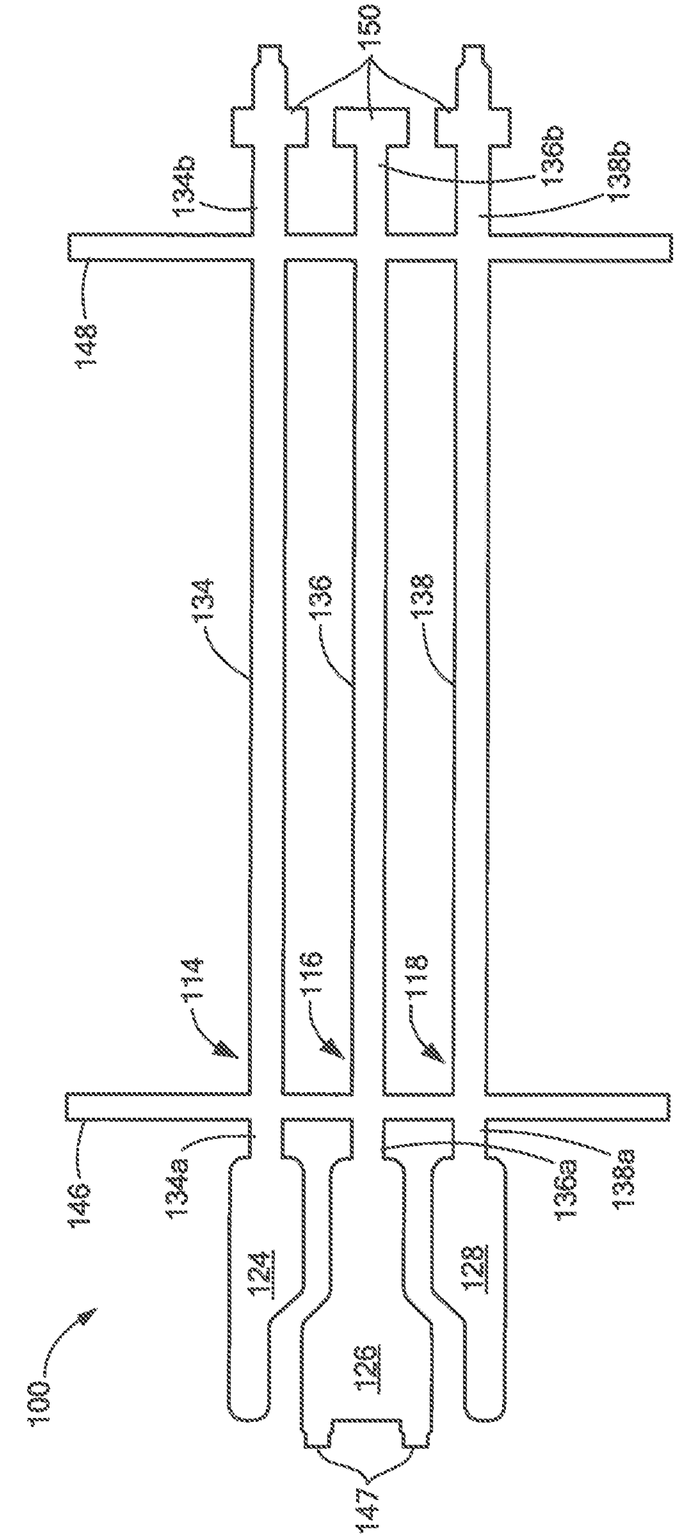
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FIG. 5

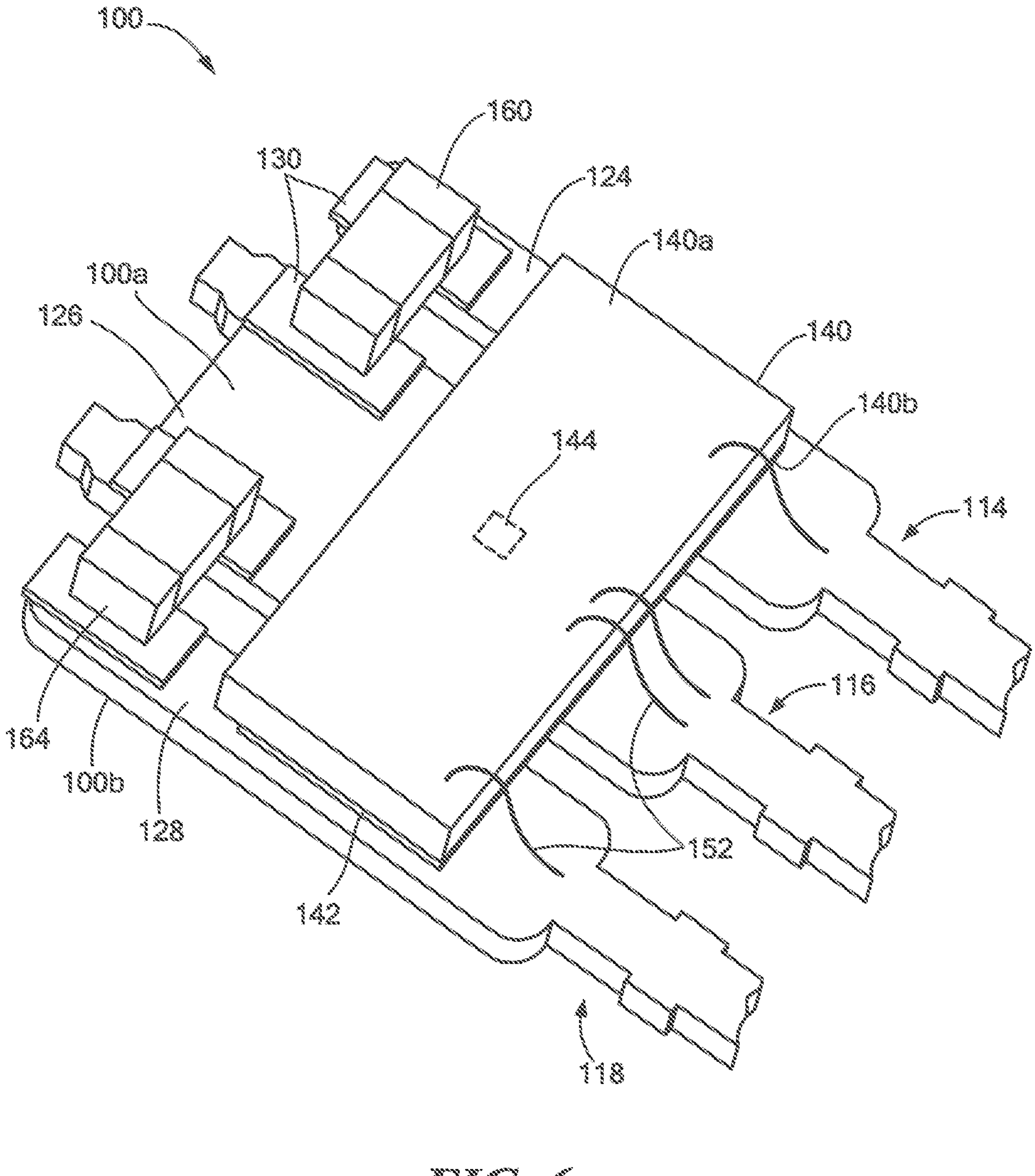
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FIG. 6

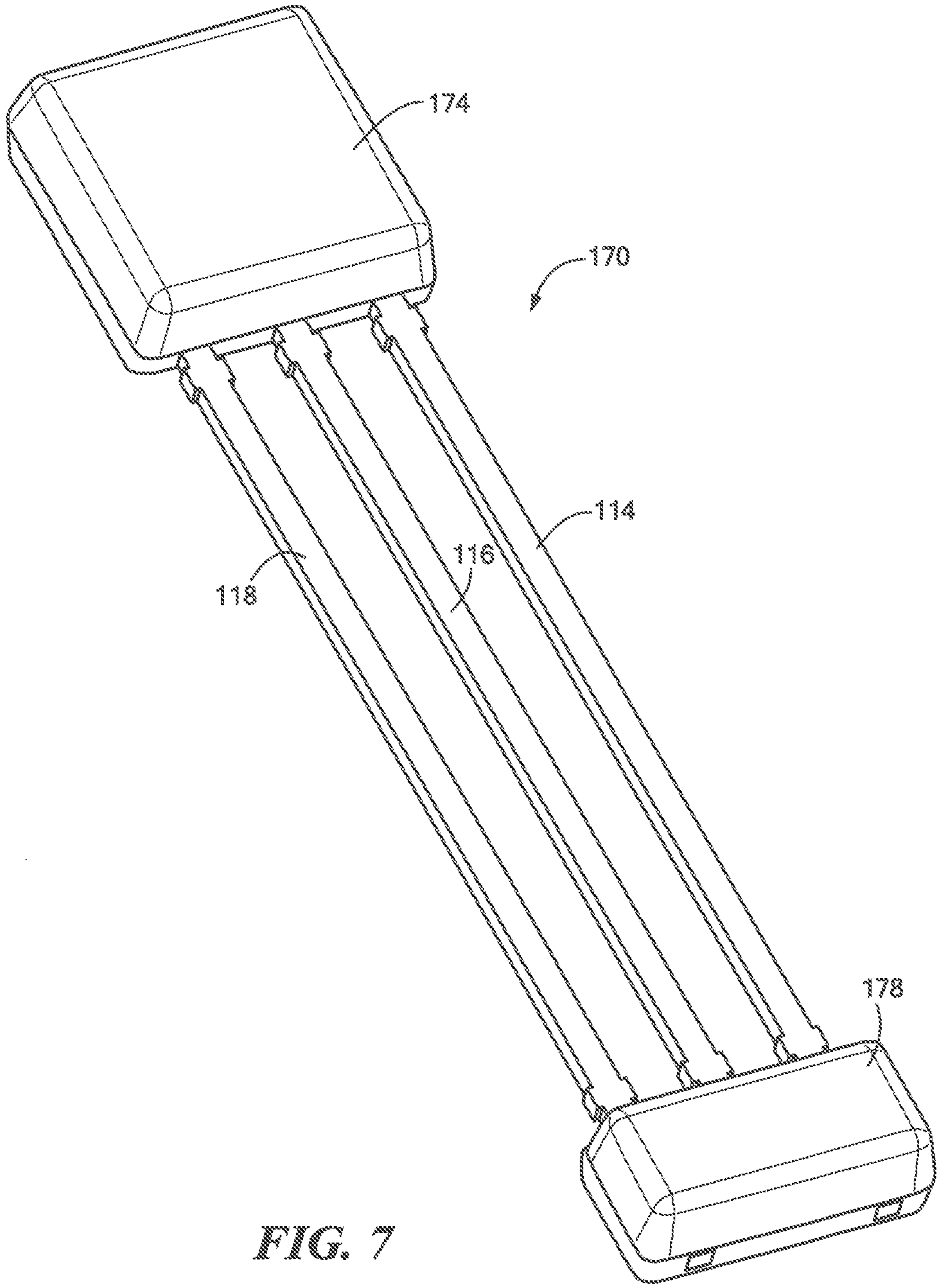
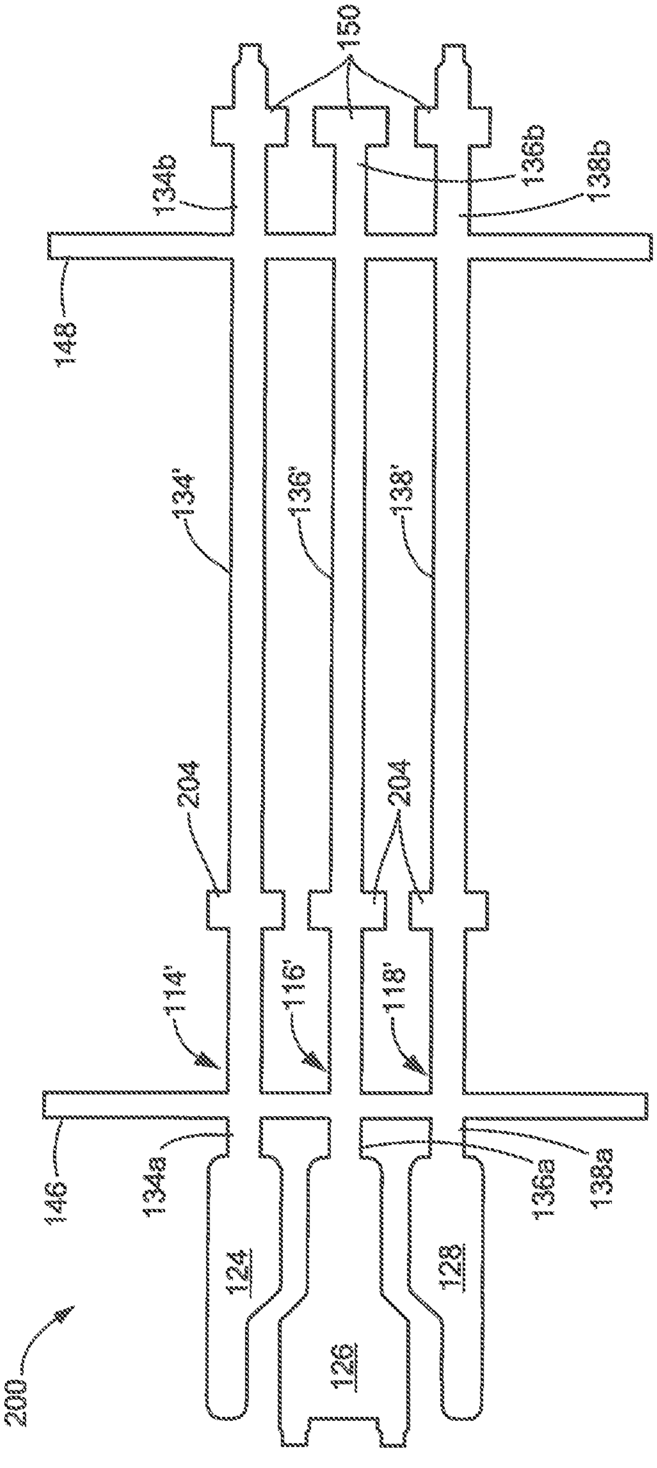


FIG. 7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128
200

FIG. 8

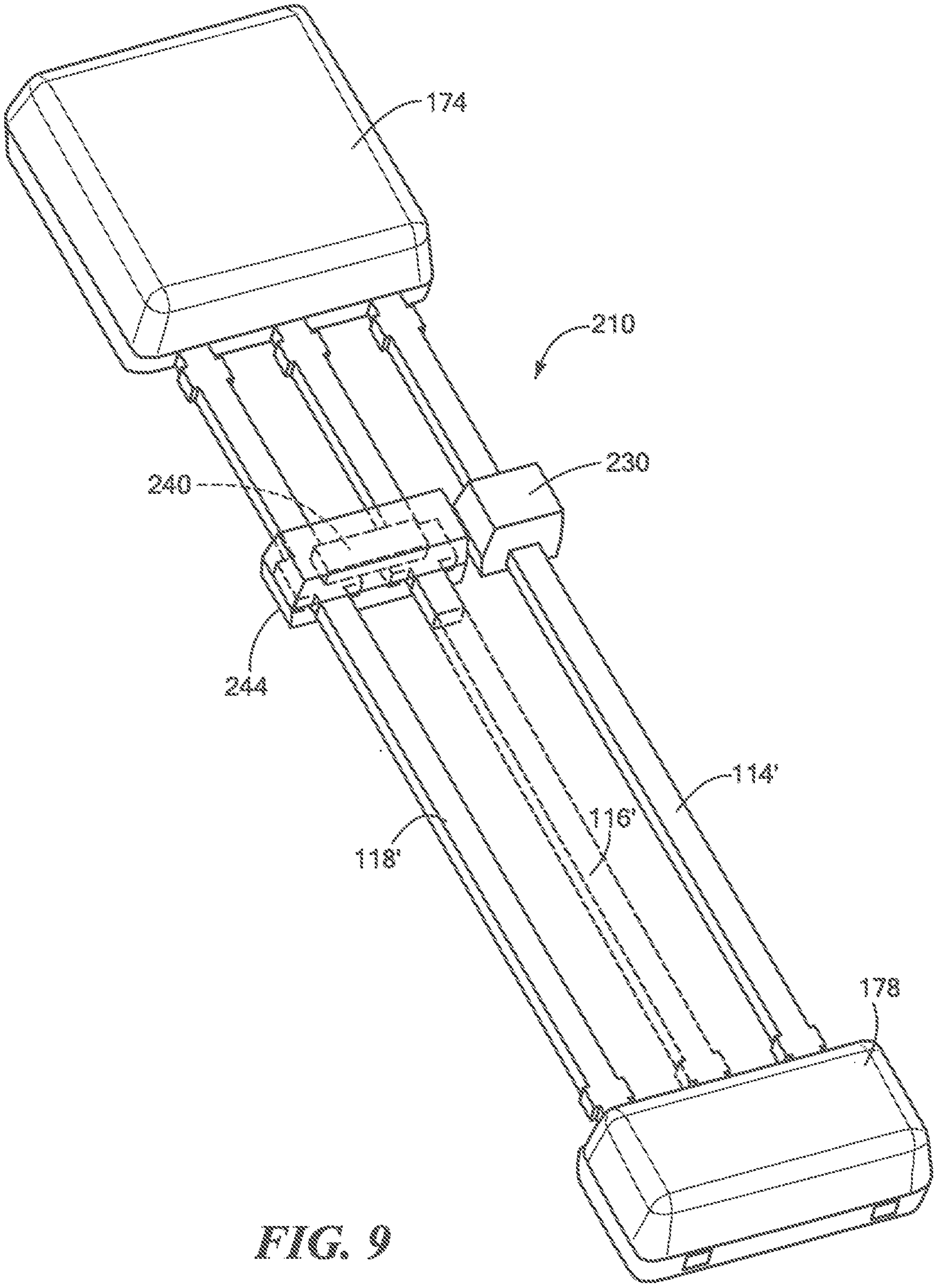

FIG. 9

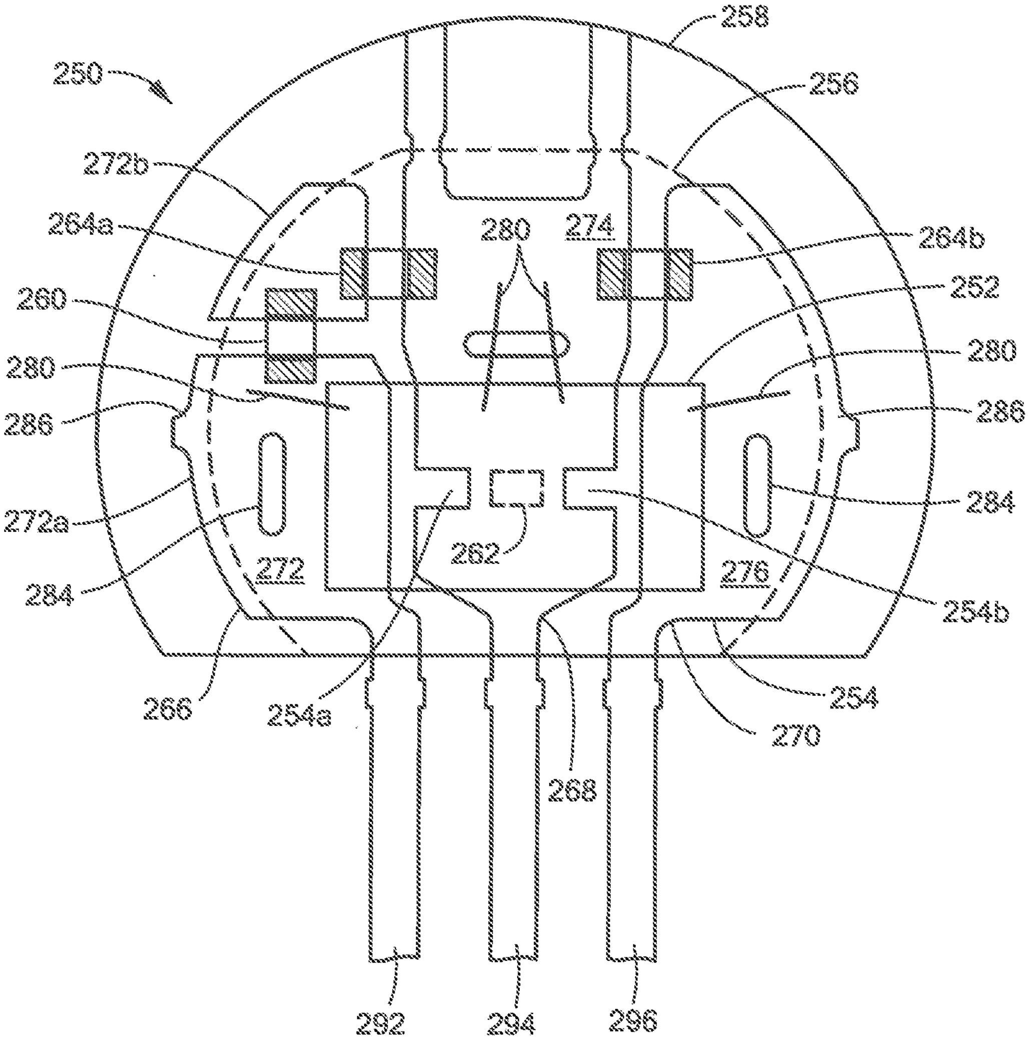

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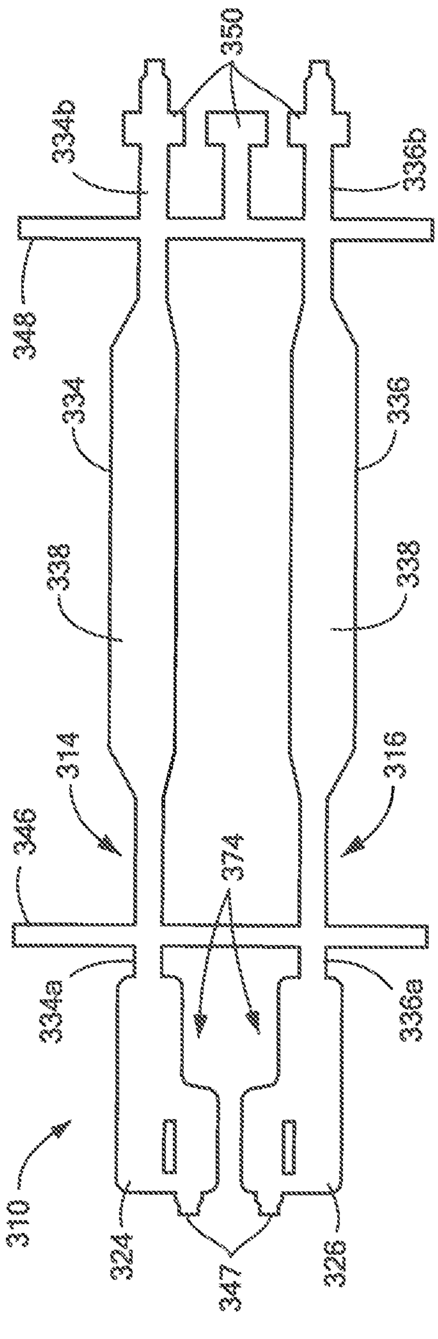
FIG. 10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326

FIG. 11

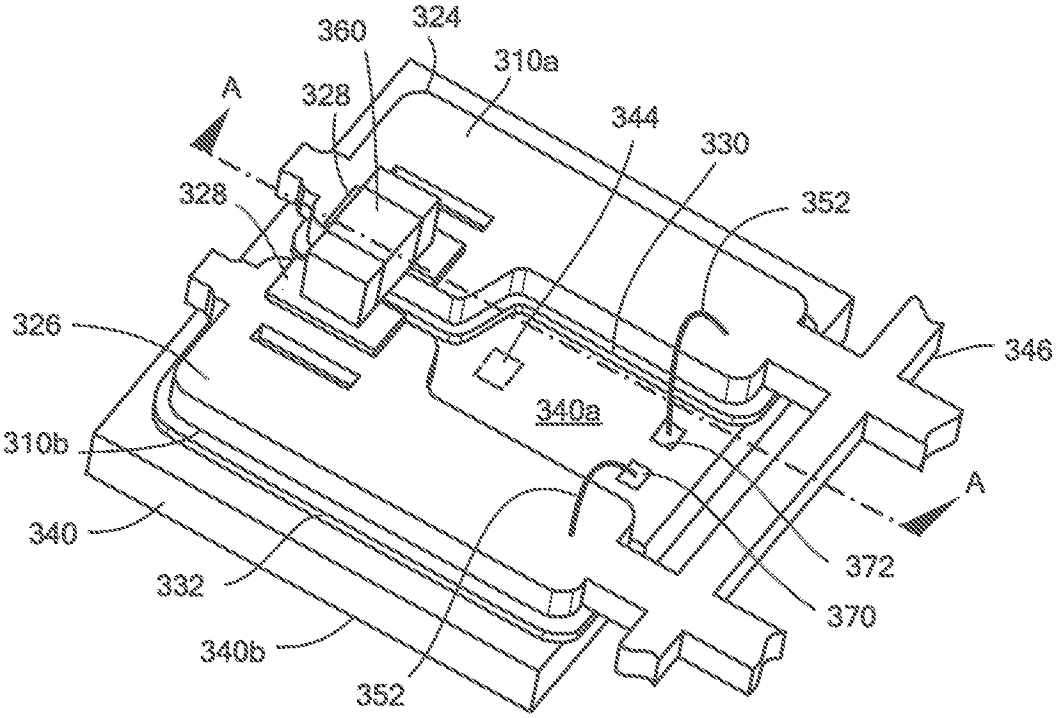

FIG. 11A

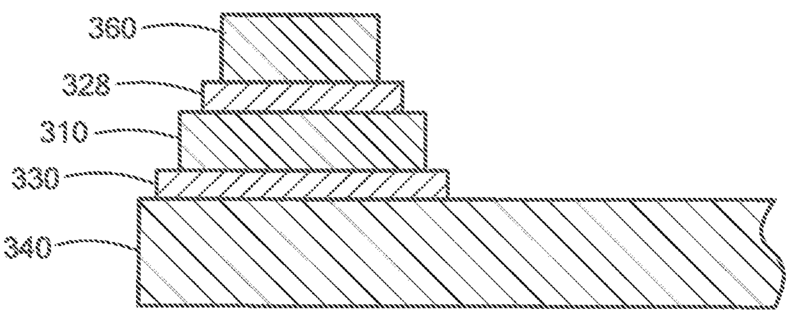

FIG. 11B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2013/030112

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/00 H01L23/495
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 10 2004 060298 A1 (BOSCH GMBH ROBERT [DE]) 22 June 2006 (2006-06-22)	1,2,9, 10,14,18
Y	figures 1,3 paragraphs [0008], [0009], [0010], [0011], [0021], [0022], [0023], [0025]; figure 2	3,7-9, 11-13, 15-17, 19-37
Y	US 2010/141249 A1 (ARARAO VIRGIL [US] ET AL) 10 June 2010 (2010-06-10)	3-5, 15-17, 27-31, 35-37
A	claim 20; figures 1b,1c,2b,2c,4 paragraphs [0022], [0024], [0025] paragraph [0046] - paragraph [0049] paragraphs [0053], [0057], [0058], [0061]	2,20-22, 26

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 August 2013	03/09/2013

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Hof, Klaus-Dieter

4

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	US 2009/140725 A1 (AUSSERLECHNER UDO [AT]) 4 June 2009 (2009-06-04) figures 7,8 paragraph [0026] paragraph [0032] - paragraph [0034] paragraph [0049] - paragraph [0051] -----	15,33,34 2
Y	WO 2008/008140 A2 (ALLEGRO MICROSYSTEMS INC [US]; SHARMA NIRMAL [US]; ARARAO VIRGIL [US];) 17 January 2008 (2008-01-17) figures 1,4A,4E,7a,7b,9a,9c,12Cn page 4, line 9 - line 21 page 7, line 5 - page 8, line 16 -----	3,4,6-8, 13, 20-22,35
Y A	WO 99/14605 A1 (INST OF QUANTUM ELECTRONICS [CH]; STEINER RALPH [CH]; SCHNEIDER MICHAE) 25 March 1999 (1999-03-25) figures 1,5 -----	23, 27-31, 35-37 26
X Y	US 2006/152210 A1 (MANGTANI VIJAY [US] ET AL) 13 July 2006 (2006-07-13) figures 1,2,5,6,13a paragraphs [0003], [0081] paragraph [0032] - paragraph [0039] -----	1,19, 23-26,32 19,23-37
Y	US 2002/195693 A1 (LIU SHENG-TSUNG [TW] ET AL) 26 December 2002 (2002-12-26) figures 3,4 paragraphs [0007], [0009] paragraph [0023] - paragraph [0024] -----	3-6,11, 12
Y	EP 0 409 173 A2 (NEC CORP [JP]) 23 January 1991 (1991-01-23) paragraph [0012]; figure 1a -----	8
Y	US 2004/145043 A1 (HAYASHI KENICHI [JP] ET AL) 29 July 2004 (2004-07-29) paragraph [0063]; figures 2b,7 -----	8
Y	US 5 500 589 A (SUMCAD GUSTAVO L [US]) 19 March 1996 (1996-03-19) figure 13 -----	8
Y	US 2008/237818 A1 (ENGEL RAYMOND W [US] ET AL) 2 October 2008 (2008-10-02) figure 1a -----	8
Y	US 5 891 377 A (LIBRES JEREMIAS L [US] ET AL) 6 April 1999 (1999-04-06) abstract -----	8
Y	US 3 627 901 A (HAPP MARVIN B) 14 December 1971 (1971-12-14) figures 9,11 ----- -/--	8

4

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	DE 10 2008 064047 A1 (CONTINENTAL TEVES AG & CO OHG [DE]) 8 April 2010 (2010-04-08) figures 2,3 paragraph [0083] - paragraph [0084]	8 16,17
Y	US 5 068 712 A (MURAKAMI GEN [JP] ET AL) 26 November 1991 (1991-11-26) figures 1,6,15,21a,23 column 17, line 5 - line 16	8
Y A	US 2005/236698 A1 (OZAWA ISAO [JP] ET AL) 27 October 2005 (2005-10-27) figures 1,2 paragraphs [0007], [0040]	9 1
Y	US 2011/133732 A1 (SAUBER JOHN B [US]) 9 June 2011 (2011-06-09) figures 1,2,3 paragraphs [0003], [0004], [0014], [0016], [0025]	13
Y	US 2010/295140 A1 (THEUSS HORST [DE] ET AL) 25 November 2010 (2010-11-25) figures 2,5,7,8 paragraph [0031] - paragraph [0036] paragraph [0040] paragraph [0044] - paragraph [0046] paragraphs [0056], [0058]	15,33,34
Y	US 2011/127998 A1 (ELIAN KLAUS [DE] ET AL) 2 June 2011 (2011-06-02) figures 10,13 paragraphs [0041], [0042], [0045], [0056], [0057]	15,33,34
X Y	US 2006/181263 A1 (DOOGUE MICHAEL C [US] ET AL) 17 August 2006 (2006-08-17) figure 1 paragraph [0033] - paragraph [0035]	1,19 19
A	DE 10 2009 000460 A1 (BOSCH GMBH ROBERT [DE]) 29 July 2010 (2010-07-29) figures 1,2 paragraph [0018] - paragraph [0023]	20-22
A	EP 2 366 976 A1 (NXP BV [NL]) 21 September 2011 (2011-09-21) claims 1,5	3
A	EP 1 160 887 A2 (MANNESMANN VDO AG [DE] SIEMENS VDO AUTOMOTIVE CORP [US]) 5 December 2001 (2001-12-05) figures 2,3 paragraph [0015] - paragraph [0018]	3-7

4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/030112

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2013/030112

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 102004060298 A1	22-06-2006	DE 102004060298 A1	22-06-2006
		JP 2006170999 A	29-06-2006
US 2010141249 A1	10-06-2010	DE 112009003555 T5	30-08-2012
		JP 2012511152 A	17-05-2012
		US 2010141249 A1	10-06-2010
		US 2012013333 A1	19-01-2012
		WO 2010065315 A1	10-06-2010
US 2009140725 A1	04-06-2009	DE 102008058895 A1	25-06-2009
		US 2009140725 A1	04-06-2009
		US 2012319682 A1	20-12-2012
WO 2008008140 A2	17-01-2008	CN 101467058 A	24-06-2009
		EP 2041592 A2	01-04-2009
		JP 2009544149 A	10-12-2009
		KR 20090031757 A	27-03-2009
		US 2008013298 A1	17-01-2008
		US 2012086090 A1	12-04-2012
		WO 2008008140 A2	17-01-2008
WO 9914605 A1	25-03-1999	AT 322023 T	15-04-2006
		DE 69834043 T2	16-11-2006
		EP 0944839 A1	29-09-1999
		ES 2262241 T3	16-11-2006
		US 6356068 B1	12-03-2002
		WO 9914605 A1	25-03-1999
US 2006152210 A1	13-07-2006	NONE	
US 2002195693 A1	26-12-2002	TW 488054 B	21-05-2002
		US 2002195693 A1	26-12-2002
EP 0409173 A2	23-01-1991	DE 69013254 D1	17-11-1994
		DE 69013254 T2	24-05-1995
		EP 0409173 A2	23-01-1991
		JP H088330 B2	29-01-1996
		JP H0350859 A	05-03-1991
		US 5089876 A	18-02-1992
US 2004145043 A1	29-07-2004	CN 1487782 A	07-04-2004
		JP 2004063688 A	26-02-2004
		KR 20040025545 A	24-03-2004
		US 2004145043 A1	29-07-2004
US 5500589 A	19-03-1996	DE 19680088 T1	17-04-1997
		JP 2929238 B2	03-08-1999
		JP H09505410 A	27-05-1997
		US 5500589 A	19-03-1996
		WO 9622543 A1	25-07-1996
US 2008237818 A1	02-10-2008	CN 101681894 A	24-03-2010
		CN 102339765 A	01-02-2012
		DE 112008000759 T5	04-02-2010
		JP 2010522994 A	08-07-2010
		KR 20090125818 A	07-12-2009
		US 2008237818 A1	02-10-2008
		US 2010330708 A1	30-12-2010

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2013/030112

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		WO 2008121443 A1	09-10-2008
US 5891377 A	06-04-1999	DE 69636589 T2	09-08-2007
		EP 0747942 A2	11-12-1996
		JP H09107061 A	22-04-1997
		SG 44042 A1	14-11-1997
		US 5891377 A	06-04-1999
		US 5949132 A	07-09-1999
US 3627901 A	14-12-1971	NONE	
DE 102008064047 A1	08-04-2010	CN 102171536 A	31-08-2011
		DE 102008064047 A1	08-04-2010
		EP 2338034 A2	29-06-2011
		KR 20110079684 A	07-07-2011
		US 2011179889 A1	28-07-2011
		US 2013175733 A1	11-07-2013
		WO 2010037812 A2	08-04-2010
US 5068712 A	26-11-1991	US 5068712 A	26-11-1991
		US 5358904 A	25-10-1994
		US 5530286 A	25-06-1996
		US 5612569 A	18-03-1997
		US 5821606 A	13-10-1998
		US 6100115 A	08-08-2000
		US 6100580 A	08-08-2000
		US 6124629 A	26-09-2000
US 2005236698 A1	27-10-2005	JP 4372022 B2	25-11-2009
		JP 2005340766 A	08-12-2005
		KR 20060047469 A	18-05-2006
		US 2005236698 A1	27-10-2005
US 2011133732 A1	09-06-2011	DE 112010004674 T5	17-01-2013
		JP 2013513104 A	18-04-2013
		US 2011133732 A1	09-06-2011
		WO 2011068653 A1	09-06-2011
US 2010295140 A1	25-11-2010	DE 102010016584 A1	25-11-2010
		US 2010295140 A1	25-11-2010
US 2011127998 A1	02-06-2011	CN 102142515 A	03-08-2011
		DE 102010060892 A1	09-06-2011
		US 2011127998 A1	02-06-2011
US 2006181263 A1	17-08-2006	NONE	
DE 102009000460 A1	29-07-2010	DE 102009000460 A1	29-07-2010
		WO 2010086055 A1	05-08-2010
EP 2366976 A1	21-09-2011	NONE	
EP 1160887 A2	05-12-2001	CN 1327268 A	19-12-2001
		EP 1160887 A2	05-12-2001
		JP 5174298 B2	03-04-2013
		JP 2002050808 A	15-02-2002
		US 6501270 B1	31-12-2002

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1, 2, 15, 20-22, 26, 28-30, 33, 35-37

   the sensor comprising a non-conductive mold material enclosing the semiconductor die and the die attach portion of the at least two leads, providing electrical isolation and protection of sensor

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2. claims: 3-7, 11, 12, 20-22, 27, 31, 35-37

   the magnetic field sensor further comprising a passive component coupled to at least two of the plurality of leads or further comprising a passive component coupled between the first portion and the second portion allowing modification of sensors input/output signals

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3. claim: 8

   a sensor wherein the connection portion of the at least one of the at least two leads has a widened portion extending away from another one of the at least two leads resulting in a larger area of at least some of the leads and thus facilitating handling of the IC during assembly

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4. claims: 9, 10

   a sensor further comprising a wire bond coupled ... distal or ... coupled ... proximate, thus defining electrical connection between die and leads

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5. claim: 13

   slot in die attach portion, thus reducing size of closed loops

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6. claims: 15-17

   ferromagnetic (mold) material

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7. claims: 14, 18, 19

   attachment between die and lead frame

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8. claims: 23-37

   lead on chip arrangement

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FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210
