



(51) International Patent Classification:

B62D 5/04 (2006.01) H02K 5/22 (2006.01)
H02K 11/33 (2016.01)

(21) International Application Number:

PCT/EP2020/062851

(22) International Filing Date:

08 May 2020 (08.05.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(71) Applicant: HELLA GMBH & CO. KGAA [DE/DE];
Rixbecker Straße 75, 59552 Lippstadt (DE).

(72) Inventors: ROCKSTEIN, Martin; Beckumer Straße 130,
59552 Lippstadt (DE). DAUTZENBERG, Bernd; Gottes-
garten 4, 59557 Lippstadt (DE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

(54) Title: ELECTRONIC CONTROL UNIT AND ELECTRIC POWER STEERING SYSTEM

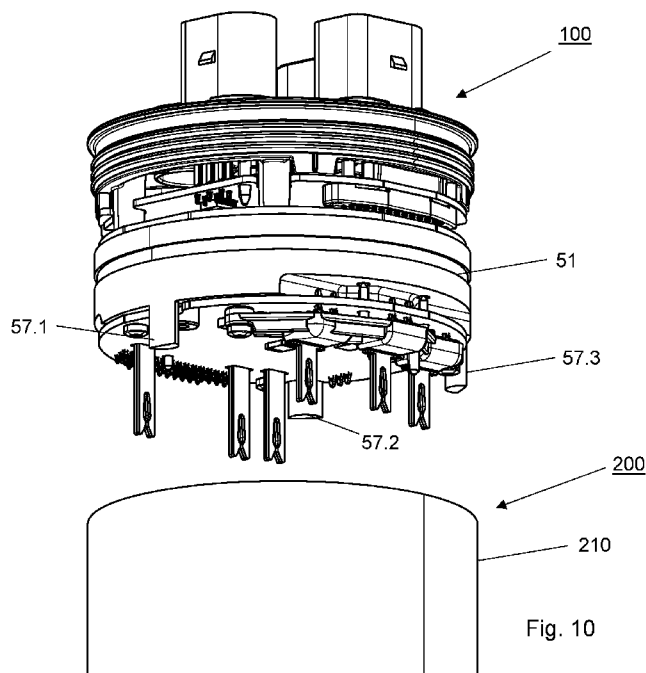


Fig. 10

(57) Abstract: The invention relates to an electronic control unit (100) for an electric power steering system (200), the electric power steering system (200) comprising a housing (210) and an electric motor, the electronic control unit (100) being configured to be arranged inside the housing (210) and to be electrically connected to the electric motor, whereby the electronic control unit (100) comprises at least one power board (30, 40) and a heat sink (50), the at least one power board (30, 40) being attached to the heat sink (50), and whereby a heat sink edge (59) of the heat sink (50) comprises a groove (51) arranged for crimping the housing (210) into the groove (51) and thereby securing the heat sink (50) with the housing (210). The invention further relates to an electric power steering system (200).

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW,
KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

Electronic control unit and electric power steering system

Description

The invention is directed at an electronic control unit for an electric power steering system and an electric power steering system.

In the electric power steering system, the electronic control unit can be connected with an electric motor for supplying power to the electric motor from a power source such as a battery. The electric power steering system can assist in a handling operation, typically a steering, of a transportation equipment, either by a driver or a machine in an autonomous vehicle. The transportation equipment can be an automobile.

The electric power steering system may further comprise a torque sensor, a steering shaft, a handle, typically a steering wheel, and the power source. In the following, a typical arrangement and operation of the electric power steering apparatus in an automobile will be described.

The torque sensor may be mounted on the steering shaft. Upon rotating the steering shaft by operating the handle, the torque sensor detects a torque being applied to the steering shaft by the operation of the handle. Upon detection of the torque by means of the torque sensor, a torque signal is output from the torque sensor to the electronic control unit. The electronic control unit then drives the electric motor based at least on the torque signal. Optionally, the control device may include further data such as vehicle speed in addition to the torque signal for controlling the driving of the electric motor.

The electronic control unit drives the electric motor by supplying a driving current from the power source, such as the battery of the automobile, to the electric motor. A driving force generated from the electric motor is then transmitted to the wheels directly or via a gearbox depending on the configuration in the automobile. As a result,

the electric power steering apparatus changes a steering angle of the wheels by amplifying the torque of the steering shaft by means of the electric motor. This enables the driver to operate the handle with less force.

The electronic control unit comprises a power board electrically connected with the electric motor. The power to the electric motor is transmitted via this power board. Thereby, the power board generates heat during operation of the electronic control unit. To prevent overheating and damage of the electronic control unit, a heat sink may be provided inside of the electronic control unit and arranged in thermal contact with a housing of the electric power steering system or electric motor.

DE 10 2007 014 645 A1 describes an electrical assembly for an electric power steering system of a motor vehicle. An electric motor is arranged within a tubular housing made of a heat-conducting material with an electronic control unit for controlling the electric motor and with a heat sink connected to the housing of the electric motor for dissipating heat from power components. The heat sink is inserted into the tubular housing, whereby a radial edge and the radial edge has a diameter corresponding in size to the inner diameter of the tubular housing.

In the known configurations of the heat sink inside the housing, the heat generated by the power board inside the electronic control unit may be dissipated through the housing of the electric power steering system or the electric motor. However, it is desirable to further improve the heat dissipating characteristics of the electronic control unit at a low cost of manufacturing of the electronic control unit and the electric power steering system.

Therefore, it is an object of the present invention, to improve the electronic control unit for an electric power steering system and an electric power steering system known from the state of the art, in particular to provide an electronic control unit for an electric power steering system and an electric power steering system having improved heat

dissipating characteristics, which are yet easy to assemble and have low cost of manufacturing.

This problem is solved by the claims. Therefore, this object is solved by an electronic control unit according to independent claim 1 and an electric power steering system according to dependent claim 15. Further details of the invention unfold from the dependent claims 2 to 14 as well as the description and the drawings. Thereby, the features and details described in connection with the electronic control unit of the invention apply in connection with the electric power steering system and the other way around, so that regarding the disclosure of the individual aspects of the invention it is or can be referred to one another.

According to a first aspect of the invention, the problem is solved by an electronic control unit for an electric power steering system, the electric power steering system comprising a housing and an electric motor, the electronic control unit being configured to be arranged inside the housing and to be electrically connected to the electric motor, whereby the electronic control unit comprises at least one power board and a heat sink, the at least one power board being attached to the heat sink, and whereby at least one circumferential outer surface of a heat sink edge of the heat sink is in direct contact with an inner surface of the housing such that heat generated by the at least one power board is conducted via the heat sink to the housing.

The heat generated in the operation of the electronic control unit may be efficiently transported along the circumferential outer side of the heat sink edge of the heat sink to the inner surface of the housing. Thereby, the heat is transported from inside of the electronic control unit, where it is generated, to the housing. The housing can be provided with a much larger surface than the heat sink itself. The heat transported thereto may thus dissipate faster and easier at the housing. Further, the housing may be efficiently cooled by means of the ambient air, for example.

In particular, an outer diameter of the circumferential outer surface of the heat sink edge may be equal or substantially equal to an inner diameter of the inner surface of the housing. Substantially includes deviations from a mathematically perfect equality due to technical reasons such as precision of manufacturing. Thereby, the circumferential outer surface is brought into close and intimate contact with the housing such that the heat generated in the at least one power board may be effectively transferred to the housing via the heat sink.

The electric motor may in particular be arranged inside the housing. The housing may in particular be an electric motor housing, i.e. the housing of the electric motor. The housing may in particular have a tubular shape. The housing may further in particular have a circular or elliptical cross section. Also, the housing may be made from a heat-conducting material. The heat-conducting material may in particular be or comprise a metal such as aluminum, magnesium, copper or similar.

The at least one power board may be fitted onto the heat sink. The at least one power board may be surrounded by the heat sink edge. The at least one power board may in particular be provided as a printed circuit board. The at least one power board may comprise electronic components such as coils and capacitors for enabling the power board to transmit power from a power source to the electric motor.

The electronic control unit may further comprise a logic board. The logic board may in particular be provided as a printed circuit board. The logic board does not have to be attached to the heat sink. In particular, the logic board may not be attached to the heat sink. The logic board in operation of the electronic control unit generates less heat than the at least one power board and thus it may be prioritized that the at least one power board that is generating more heat in operation of the electronic control unit is attached to the heat sink.

Also, the electronic control unit may further comprise a connector plate. The connector plate may be made from plastic, for example. The connector plate may be formed as a

cap for sealing the housing at an end thereof. The connector plate may be provided with a sealing for sealing the inside of the housing against the outside. The sealing may be made from a silicone rubber. The connector plate may comprise one, two, three or more connectors, in particular plug connectors. At or inside of the plug connectors, the connector plate may be provided with electrical contacts. The electrical contacts may be made from a copper alloy, for example, to provide great electrical conductivity. One or multiple of the plug connectors may be provided for contacting a control board of the transportation equipment with the logic board. Thereby, the torque sensor, other sensors and/or other electronic control units may be connected to the logic board. These plug connectors may be connected by means of power connectors to the at least one power board.

It is possible, that the heat sink comprises a groove arranged for crimping the housing into the groove and thereby securing the heat sink with the housing.

When crimping the housing into the groove of the heat sink, a particularly tight fitting of the heat sink inside of the housing is achieved and the thermal conductivity from the heat sink to the housing may also be improved. The groove arranged for crimping the housing into the groove may thus also be configured for thereby thermally connecting the heat sink with the housing. Further, the overall contact surface of the heat sink with the housing and thereby the overall thermal conductivity from the heat sink to the housing is even further improved. Also, providing the heat sink with the groove may be performed at relatively low cost when manufacturing the heat sink and the crimping of the housing into the groove is a relatively simple, fast and cost-effective way of securing the heat sink and in particular in the entire electronic control unit with the housing of the electric power steering system.

The crimping may be performed by squeezing the housing at its outer side into the groove. Thereby, the housing is deformed plastically and contacted with the heat sink at its groove. The groove may have a rectangular, U-type or V-type shape, for example. Also, it is possible to provide more than just one groove for crimping it with

the housing in the heat sink. For example, the heat sink edge of the heat sink may comprise at least two grooves for crimping the housing into the at least two grooves.

It is possible, that the groove is a circumferential groove such that it is arranged around at least half of the circumference of the heat sink edge of the heat sink, preferably around the entire circumference of the heat sink. Thereby, particularly simple crimping around the circumference of the heat sink edge and the housing may be performed and a particularly secure connection of the heat sink with the housing may be achieved.

Further, it is possible, that the groove is arranged in between two circumferential outer surfaces of the heat sink edge directly connecting the heat sink with the housing. Thereby, the housing may be crimped into the groove in between the two circumferential outer surfaces of the heat sink edge such that the housing is crimped in between the two circumferential outer surfaces. This provides for a particularly secure connection of the heat sink with the housing. In particular, an outer diameter of the two circumferential outer surfaces of the heat sink edge may be equal or substantially equal to an inner diameter of the inner surface of the housing. Substantially includes deviations from a mathematically perfect equality due to technical reasons such as precision of manufacturing. Thereby, the two circumferential outer surfaces are brought into close and intimate contact with the housing such that the heat generated in the at least one power board may be effectively transferred to the housing via the heat sink.

Further, it is possible that the crimped housing at the groove is thermally connecting the heat sink with the housing. Thereby, the heat conduction from the heat sink to the housing may be improved.

It is also possible, that the electronic control unit comprises a first power board and a second power board as the at least one power board, the heat sink being sandwiched in between the first power board and the second power board. The first power board

and second power board may each be provided as redundant power boards for supplying the electric motor independently from one another with power. Both, the first power board and the second power board may be arranged each with three phases of electricity to supply three-phase electric power to the electric motor. Together, the first power board and the second power board may thus be arranged to supply six phases of electricity to the electric motor. The first power board may be provided on one side of the heat sink and the second power board may be provided on another side of the heat sink. The first power board and the second power board may be directly attached with their circuit board and electronic components to the heat sink. A thermal interface material may be provided between the first power board and the heat sink and the second power board and the heat sink to thermally attached the respective parts with each other for better thermal conductivity.

Also, it is possible, that electronic components of the first power board and electronic components of the second power board are facing towards the heat sink. Further, it may be provided, that the electronic components extend toward the heat sink. In particular, it may be provided, that the electronic components at least partially extend inside the heat sink.

Moreover, it is possible, that the heat sink is configured as an at least partially circular heat plate. In particular, the heat sink may be at least a half or fully circular heat plate. The heat sink edge of the heat sink may have or circumscribe the circular form of the heat plate. The heat sink may be a flat plate in the sense that its thickness is less than its diameter or radius.

Further, it is possible, that the heat sink comprises several heat conduction surfaces arranged in contact with electronic components of the at least one power board. Thermal interface material may be provided in between the electronic components and the heat conduction surfaces. Thereby, heat generated by the electronic components may be conducted to the heat sink very effectively.

Thereby, it is possible, that the several heat conduction surfaces are arranged at different heights along a thickness of the heat sink to accommodate electronic components of different height. Thereby, the design freedom of the at least one power board with regard to its specific electronic components, such as their size and geometry, may be maintained while still enabling a high thermal conductivity of the at least one power board to the heat sink. In other words, the heat sink may be adapted in its form and geometry to the at least one power board and not the other way around.

It is also possible, that the heat sink comprises heat sink through holes and at least one power board of the at least one power board is secured to the heat sink by means of bolts passing through the heat sink through holes and being fastened in domes extending from a connector plate of the electronic control unit. This enables a simple yet reliable and detachable connection of the at least one power board with the heat sink and further with the connector plate. Moreover, a logic board of the electronic control unit may thereby be sandwiched and easily secured in between the at least one power board and the connector plate by arranging it in between these.

Alternatively, or additionally, it is possible, that the heat sink comprises heat sink holes and at least one power board of the at least one power board is secured to the heat sink by means of bolts being fastened in the heat sink holes. Thereby, a simple yet reliable and detachable connection between the at least one power board with the heat sink is provided.

In particular, when a first power board and a second power board of the at least one power board are provided, the first power board may be attached by means of the heat sink through holes and the domes in the connector plate and the second power board may be attached by means of the holes in the heat sink. This provides for particularly good serviceability, because the second power board may be exchanged without demounting the first power board from the heat sink and further improves the reliability of the secure connection.

It is further possible, that the heat sink comprises heat sink recesses for second power connectors of the electronic control unit, the second power connectors extending from a connector plate of the electronic control unit through the heat sink recesses inside of the heat sink to at least one power board of the at least one power board. These second power connectors may be used for transferring current from the connector plate, which may be connected to the power source, to the at least one power board. The heat sink recesses allow for simple yet cost-effective design of the heat sink and the second power connectors. The heat sink recesses may be designed as flat slots. The second power connectors may be designed as second power cables or second power lugs. The second power connectors may have flat and/or rectangular shape.

The term second in the second power connectors is not limiting in the sense that there must be first power connectors as well. However, in a configuration with two power boards, a first power board and a second power board of the at least one power board, it may be possible to provide first power connectors for connection with the first power board. Then, the second power connectors are connected to the second power board. Thereby, each of the two power boards may be separately provided with current for transmitting it to the electric motor as driving current.

It is also possible, that the heat sink comprises a heat sink cutout, in particular extending from the heat sink edge to an inside of the heat sink, a second logic connector extending from a logic board of the electronic control unit through the heat sink cutout to at least one power board of the at least one power board. The heat sink cutout may have a partially circular and/or partially flat shape. The heat sink cutout allows for simple yet cost-effective design of the heat sink and the second logic connector.

The term second in the second logic connector is not limiting in the sense that there must be a first logic connector as well. However, in a configuration with two power boards, a first power board and a second power board of the at least one power

board, it may be possible to provide a first logic connector for connection of the logic board with the first power board. Then, the second logic connector may be connected to the second power board. Thereby, each of the two power boards may be separately provided with signals or instructions from the logic board for transmitting driving current to the electric motor.

Thereby, it is possible, that a first electric motor connector from a power board of the at least one power board extends through the heat sink cutout for connection with the electric motor of the electric power steering system. Thereby, the number of cutouts or recesses may be reduced and the electronic control unit may have a compact design. By means of the first electric motor connector, driving current from a power board of the at least one power board may be transmitted along the electronic control unit, passing by the heat sink, to the electric motor.

Again, the term first in the first electric motor connector is not limiting in the sense that there must be a second electric motor connector as well. However, in a configuration with two power boards, a first power board and a second power board of the at least one power board, it may be possible to provide a second electric motor for connection of the second power board with the electric motor. Then, the first electric motor connector may be connected to the first power board. Thereby, each of the two power boards may separately transmit driving current to the electric motor.

Further it is possible, that the heat sink comprises heat sink projections projecting from the heat sink beyond the at least one power board and being arranged to rest on an inner rim inside of the housing of the electric power steering system. By means of the heat sink projections, when installing the electronic control unit in the housing, the end position of the electronic control unit in the housing may be easily detected. The end position is achieved when the projections rest on the inner rim inside the housing and the electronic control unit cannot be pushed into the housing any further without using excessive force to bend or damage the projections. Thereby, a defined position at which the housing is crimped into the groove is provided and the crimping can be

performed at that defined position every time when joining the heat sink with the housing facilitating the manufacture.

According to a second aspect of the invention, the problem raised in the introduction of this description is solved by an electric power steering system comprising the electronic control unit according to the first aspect of the invention, whereby the electric motor of the electric power steering system is electrically connected to the at least one power board by means of at least one electric motor connector, and whereby the housing of the electric power steering system is crimped into the groove of the heat sink of the electronic control unit.

In a configuration with two power boards, i.e. the first power board and the second power board of the at least one power board, the electric motor may be electrically connected by means of a first electric motor connector to the first power board and by means of a second electric motor connector to the second power board. Each of the power boards may supply a three-phase electric current. The electric motor may thus be designed as a six-phase electric motor. Thereby, the electric motor can be separately driven by the driving current supplied separately by any one or both of the two power boards. This provides for a redundant and failure unsusceptible design of the electronic control unit and the electric power steering system.

When the heat sink comprises projections projecting from the heat sink beyond the at least one power board, the projections may rest on an inner rim inside of the housing of the electric power steering system. Thereby, a defined position of the electronic control unit in the housing and a stable connection therewith is achieved.

The electric power steering system may further comprise a torque sensor, a steering shaft, a handle, in particular a steering wheel, and a power source. The electric power steering system may further have the arrangement and be arranged for operation of in an automobile as described in the introductory part of this description.

Further advantages, features and details of the invention unfold from the following description, in which by reference to drawings of the following Figures an embodiment of the present invention is described in detail. Thereby, the features from the claims as well as the features mentioned in the description can be essential for the invention as taken alone or in an arbitrary combination.

In the drawings, there are shown:

- Fig. 1 an exploded illustration from a bottom side perspective view of an embodiment of the electronic control unit according to the first aspect of the invention;
- Fig. 2 an exploded illustration from a top side perspective view of the electronic control unit of Fig. 1;
- Fig. 3 a detailed illustration from a side perspective view of two power boards and a logic board of the electronic control unit of Fig. 1 and 2;
- Fig. 4 a detailed illustration from a side perspective view on the assembled logic board with the connector plate;
- Fig. 5 a detailed illustration from a side perspective view on the assembled logic board with the connector plate and the assembled first power board;
- Fig. 6 a detailed illustration from a side perspective view on a heat sink of the electronic control unit of Fig. 1 and 2;
- Fig. 7 a detailed illustration from a side perspective view on the assembly of the heat sink of Fig. 6 with the assembly of the assembled logic board with the connector plate and the first power board of Fig. 5;
- Fig. 8 a detailed illustration from a side perspective view on the assembly of the assembled logic board with the connector plate, the assembled first power board and the heat sink of Fig. 6;
- Fig. 9 an illustration from a side perspective view on the electronic control unit 100 of Fig. 1 and 2 in an assembled state;
- Fig. 10 an illustration from a side perspective view on a process of assembling the electronic control unit of Fig. 9 with an embodiment of the electric power

steering system of the invention; and

Fig. 11 an illustration of a sectional cut through the electric power steering system of Fig. 10 with the electronic control unit assembled inside.

Figure 1 shows an exploded illustration of an electronic control unit 100 according to an embodiment of the invention from a bottom side perspective view. According to this bottom side perspective view, bottom sides of the parts of the electronic control unit 100 are visibly illustrated.

Figure 2 shows the same electronic control unit 100 of Figure 1 with the difference that it is from a top side perspective view. According to this top side perspective view, top sides of the parts of the electronic control unit 100 are visibly illustrated.

As can be taken from Figures 1 and 2, the electronic control unit 100 comprises two power boards 30, 40, namely a first power board 30 and a second power board 40. The power boards 30, 40 may also be referred to as power-stages. The two power boards 30, 40 are arranged so as to supply an electric motor (not shown) of an electric power steering system 200 (see Figures 10 and 11) with driving current. For this purpose, the first power board 30 is connected to a first electric motor connector 80 electrically connectable with the electric motor. Further, for this purpose, the second power board 40 is connected to a second electric motor connector 90 electrically connectable with the electric motor.

Further, the electronic control unit 100 comprises a connector plate 10. The connector plate 10 comprises multiple, in this particular embodiment three, plug connectors 11.1, 11.2, 11.3. In this particular embodiment, the first plug connector 11.1 and the second plug connector 11.2 are provided with electric contacts (not shown) inside thereof. The electric contacts may be made from a copper alloy, for example, to allow for good electric conductivity. These electric contacts are arranged as first and second signal connectors 15.1, 15.2. The signal connectors 15.1, 15.2 extend from the plug

connectors 11.1, 11.2 on a top side of the connector plate 10 to a bottom side of the connector plate 10.

The electronic control unit 100 also comprises a logic board 20. The logic board 20 is arranged so as to control the two power boards 30, 40 or, in other words, the operation of the electronic control unit 100 or, in further other words, the transmission of driving current to the electric motor. For this purpose, the signal connectors 15.1, 15.2 are connected with the logic board 20. Further, the logic board 20 is connected via a first logic connector 70 to the first power board 30. Also, the logic board 20 is connected via a second logic connector 60 to the second power board 40.

Signal plugs (not shown) may be attached to the plug connectors 11.1, 11.2 for supplying signals from a sensor, such as a torque sensor, or other units, such as a further electronic control unit from a transportation equipment (not shown), such as an automobile, to the logic board 20. By means of the signals, such as a torque detected by the torque sensor or a travelling speed of the transportation equipment, the logic board 20 may control the driving current via the two power boards 30, 40.

The connector plate 10 further comprises a third plug connector 11.3. This third plug connector 11.3 comprises inside further electric contacts. These electric contacts are provided as first power connectors 16.1, 16.2 and second power connectors 17.1, 17.2. The second power connectors 17.1, 17.2 are longer than the first power connectors 16.1, 16.2 such that they may accordingly connect with their respective power boards 30, 40 at their respective distance from the connector plate 10. In this embodiment, the first power connectors 16.1, 16.2 and the second power connectors 17.1, 17.2 are provided as metal strips.

A power plug (not shown) may be connected to the third plug connector 11.3 to provide power to the first power connectors 16.1, 16.2 and second power connectors 17.1, 17.2. The power plug may be attached to a power source such as a battery (not shown) of the transportation equipment. The power source is arranged as a three-

phase electric power source. The connector plate 10 may also be referred to as a power and logic connector plate as it provides power and logic or signal processing connections to the respective boards 20, 30, 40 of the electronic control unit 100.

The first power connectors 16.1, 16.2 are connected to the second power board 40 and the second power connectors 17.1, 17.2 are connected to the first power board 30. Thereby, the first power board 30 is provided with a three-phase electric current and the second power board 40 is provided with a three-phase electric current. The electronic control unit 100 is thereby provided with six phases and the electric motor may be provided as a six-phases electric motor. When one of the two power boards 30, 40 fails due to an error, the other one can ensure safe and reliable operation of the electric motor by transmitting driving current to it. Thereby, it is prevented that an error in one of the power boards 30, 40 leads to undesirable loss of the steering function and possibly in an accident and damage of the driver and passengers of the transportation equipment.

As can further be taken from Figures 1 and 2, a heat sink 50 is arranged in between the first power board 30 and the second power board 40. The heat sink 50 is thus sandwiched in between the two power boards 30, 40. The heat sink 50 in this embodiment is provided as a die-cast aluminum. The heat sink 50 allows for the heat generated in the two power boards 30, 40 to be dissipated away. For this purpose, the heat sink 50 is connected to a housing 210 of the electric power steering system 200, which will be explained later in more detail.

Also, the connector plate 10 comprises a venting opening 13 and a venting element (not shown) for closing the venting opening 13. When the electronic control unit 100 is inserted into the housing 210, which also will be explained in more detail later, the venting element provides for pressure compensation of the inside of the housing 210 with the environment. Further, the connector plate 10 comprises a sealing 12. The sealing 12 is made from a silicone rubber in this particular embodiment. The sealing

12 seals the electronic control unit 100 inside the housing 210 against the environment when it is inserted into the housing 210.

Figure 3 shows the logic board 20, first power board 30 and second power board 40 in more detail in an exploded view. The logic board 20 comprises first electronic components 21, of which the first electronic components 21.1, 21.2, 21.3 are exemplary denominated. Further, the first power board 30 comprises second electronic components 31, of which the second electronic components 31.1, 31.2, 31.3 are exemplary denominated. Moreover, the second power board 40 comprises third electronic components 41, of which the third electronic components 31.1, 31.2, 31.3 are exemplary denominated.

The first electronic components 21 may be coils, capacitors, at least one computing unit, such as a processor, and other electronic components for enabling calculation operations based on received signals and logic communication of the logic board 20 with the two power boards 30, 40. The second and third electronic components 31, 41 may be coils, capacitors and other electronic components for enabling the respective power board 30, 40 to transmit power from a power source to the electric motor as will be explained further later.

The logic board 20, the first power board 30 and the second power board 40 are shown in an orientation with their respective top sides and bottom sides such as they are arranged within the electronic control unit 100. Thus, the largest of the second electronic components 31.1, 31.2, 31.3 on a bottom side of the first power board 30 show towards the largest of the third electronic components 41.1, 41.2, 41.3 of the second power board 40. These large electronic components 31, 41 generate a lot of heat and by virtue of this arrangement a heat sink 50 may receive the second and third electronic components 31, 41 to allow for good heat conductivity characteristics so as to remove the heat from the two power boards 30, 40 via the heat sink 50 and housing 210 effectively.

Further, the first power board 30 comprises first power board recesses 32.1, 32.2 for guiding the second power connectors 16.1, 16.2 therethrough. Also, the first power board 30 comprises power board through holes 33.1, 33.2, 33.3 for guiding bolts 1 therethrough for fastening the heat sink 50 to the connector plate 10. These features will be explained later in more detail.

Figure 4 shows an assembly of the logic board 20 with the connector plate 10. The first and second signal connectors 15.1, 15.2 are connected to the logic board 20. In particular, the first and second signal connectors 15.1, 15.2 comprise multiple pins being attached to corresponding pin receiving holes in the logic board 20.

The logic board 20 comprises two logic connectors 60, 70 connected thereto and having the purpose of enabling communication and control of the two power boards 30, 40 by means of the logic board 20. Therefore, each of the two logic connectors 60, 70, namely the first logic connector 70 and the second logic connector 60, comprises multiple electrical connector pins (not denominated). The electrical connector pins of the first logic connector 70 are relatively shorter than the electrical connector pins of the second logic connector 60. The reason for this is that the first logic connector 70 connects the logic board 20 with the first power board 30, whereby the distance between the logic board 20 and the first power board 30 in an assembled state of the electronic control unit 100 is relatively short. However, the distance between the logic board 20 and the second power board 40, which are connected by means of the second logic connector 60, is relatively longer because the first power board 30 and the heat sink 50 are arranged in between as can be seen in the assembled state of the electronic control unit 100 from Figure 10, for example.

The electrical connector pins are inserted into corresponding connector pin holes (not denominated) inside the logic board 20. The connector pin holes for the respective electrical connector pins are arranged at two opposite ends of the logic board 20. Thereby, the first logic connector 70 and the second logic connector 60 are arranged at the two opposite ends of the logic board 20. Further, the logic board 20 comprises

connection pin holes (not denominated) for corresponding first connection pins (not denominated) of the first logic connector 70 and connection pin holes for corresponding second connection pins (not denominated) of the second logic connector 60. By means of the connection pins the two logic connectors 60, 70 are securely fastened in the logic board 20.

The electrical connector pins are arranged in logic connector housings 71, 61 of the logic first logic connector 70 and the second logic connector 60. In this particular embodiment, the second logic connector housing 61 consists of two separate parts. This design may be chosen due to the long extension of the its electrical connector pins. The first part of the second logic connector housing 61 comprises the connection pins for corresponding connection pin holes of the logic board 20 and the second part of the second logic connector housing 61 comprises connection pins for securing them in corresponding connection pin holes of the second power board 40. Moreover, the first logic connector housing 71 comprises connection pins for securing them in corresponding connection pin holes of the first power board 30.

As may be taken from this Figure, the logic board 20 comprises cutouts at its edge for domes 18.1, 18.2, 18.3 projecting from the connector plate 10 towards and beyond the logic board 20. These domes 18.2, 18.3 enable fastening of the heat sink 50 with the connector plate 10 and thereby sandwiching the logic board 20 and the first power board 30 in between these as will be explained later. The domes 18.2, 18.3 may be provided with molded holes inside. The molded holes may be pre-threaded for bolts 1 or threaded by means of self-tapping bolts or screws 1.

The first power connectors 17.1, 17.2 are extending from the connector plate 10 through a cutout (not denominated) at the edge of the logic board 20 towards the first power board 30. Further, the second power connectors 16.1, 16.2 extend from the connector plate 10 next to logic board 20 and the first power connectors 17.1, 17.2 towards the second power board 40.

Figure 5 shows an assembly of the first power board 30 with the logic board 20 and the connector plate 10.

A first electric motor connector 80 comprises three first electric phase pins 82.1, 82.2, 82.3 for electric connection with the electric motor of the electric power steering system 200. The three first electric phase pins 82.1, 82.2, 82.3 are received in a first electric motor connector housing 81. The first electric motor connector housing 81 comprises connection pins (not denominated) for connection with corresponding connection pin holes (not denominated) in the first power board 30. Further, the three first electric phase pins 82.1, 82.2, 82.3 comprise at ends opposite of the ends for connecting with corresponding electric motor pins (not shown) of the electric motor several first power board connection pins (not shown) for electrically connecting these with the first power board 30.

The first logic connector 70 is connected with the first power board 30. Further, the second power connectors 16.1, 16.2 are guided through the first power board recesses 32.1, 32.2 of the first power board 30.

The first electric motor connector 80 is arranged next to the second logic connector 60 such that they may extend together along a heat sink cutout 53 as shown in the heat sink 50 of Figure 6. The first electronic components 31 of the first power board 30 extend towards the heat sink 50 to be arranged on the top side of the first power board 30.

Figure 6 shows the heat sink 50 in more detail and from its bottom side. A heat sink edge 59 of the heat sink 50 circumscribes the heat sink 50. The heat sink 50, in particular the heat sink edge 59, comprises the groove 51 for crimping the housing 210 of the electric power steering system 200 into the groove 51. Thereby, the housing 210 is mechanically secured to the heat sink 50 and ultimately to the electronic control unit 100. Further, the heat sink 50 is thermally connected to the housing 210 such that the heat generated by the two power boards 30, 40 may be

dissipated via the heat sink 50 along the housing 210 having a much larger surface area for dissipation. Also, the surface area of the housing 210 may be in thermal connection with the environment such that the housing 210 is cooled or, in other words, may exchange heat with the environment.

The groove 51 is a circumferential groove 51 such that it is arranged around the circumference of the heat sink edge 59. The heat sink edge 59 further comprises two circumferential outer surfaces 58.1, 58.2, in between which the circumferential groove 51 is provided. The two circumferential outer surfaces 58.1, 58.2 of the heat sink edge 59 are configured to contact an inner surface 211 of the housing 210 as may be taken from Figure 17. For this purpose, the outer diameter of the circumferential outer surfaces 58.1, 58.2 equals or substantially equals the inner diameter of the inner surface 211 of the housing 210.

The structure of the heat sink 50 will in the following be further explained with reference to Figures 7 and 8, Figure 7 showing a process of assembling the heat sink 50 with the first power board 30 assembled with the logic board 20 and the connector plate 10 and Figure 8 showing the assembly according to the process of Figure 7. Figure 7 and Figure 8 show a top side of the heat sink 50 whereas Figure 6 shows a bottom side of the heat sink 50.

The heat sink 50 is configured as a circular heat plate, whereby the heat sink 50 comprises a heat sink cutout 53. The heat sink cutout 53 extends from the heat sink edge 59 to an inside of the heat sink 50. The second logic connector 60 and the first electric motor connector 80 extend through the heat sink cutout 53 in the assembled state where the heat sink 50 is attached to the first power board 30 as can be seen in Figure 9.

Further, the heat sink 50 comprises several heat conduction surfaces 52 on its bottom side and on its top side for attaching them to the first power board 30 and the second power board 40, in particular the first electronic components 31 and the second

electronic components 41, by means of a thermal interface material (not shown). The heat conduction surfaces 52.1, 52.2 on the bottom side and the heat conduction surface 52.3 on the top side are exemplary denominated in the Figures 6 and 8. In the assembled state of Figure 8, the first electronic components 31 of the first power board 30 are in direct contact via the thermal interface material with the heat conduction surfaces 52.1, 52.2 on the bottom side of the heat sink 50. The heat conduction surfaces 52.1, 52.2 of the bottom side are arranged at different heights along a thickness of the heat sink 50 and thereby can accommodate or attach to first electronic components 31 of different size or height. The same can be applied to the top side such that heat conduction surfaces 52 of the top side of the heat sink 50 may be arranged at different heights along the thickness of the heat sink 50. Thereby, the first electronic components 31 are effectively transferring heat to the heat sink 50.

Moreover, the heat sink 50 comprises heat sink through holes 54.1, 54.2, 54.3 as can be seen in Figure 10 from the bottom side and in Figure 11 from the top side. The first power board 30 is secured by means of bolts 1 passing through the heat sink through holes 54 and being fastened in the domes 18.1, 18.2 of the connector plate 10. The bolts 1 further pass through the power board through holes 33.1, 33.2, 33.3 of the first power board 30 as shown in Figure.

Also, the heat sink 50 comprises heat sink recesses 15 for guiding the second power connectors 16.1, 16.2 of the connector plate 10 therethrough. This enables for the second power connectors 16.1, 16.2 to be connected to the second power board 40 when the heat sink 50 is attached to the first power board 30.

Moreover, the heat sink 50 comprises heat sink projections 57.1, 57.2, 57.3 projecting from the heat sink 50 beyond the two power boards 30, 40 in the assembled state of the electronic control unit 100 as can be seen in Figure 10. These heat sink projections 57.1, 57.2, 57.2 may be arranged resting on an inner rim 212 inside of the housing 210 of the electric power steering system 200.

The heat sink 50 also comprises heat sink holes 56.1, 56.2, 56.3 on its top side. The second power board 40 may be fastened to the heat sink 50 by means of bolts 1 in the heat sink holes 56.1, 56.2, 56.3. The heat sink holes 56.1, 56.2, 56.3 may be pre-threaded or threaded by means of self-tapping bolts or screws 1.

Figure 9 shows the electronic control unit 100 in the assembled state. The second power board 40 with the second electronic components 41 on the bottom side are attached to the heat conduction surfaces 52 of the top side of the heat sink 50. The second electric motor connector 90 comprises three second electric phase pins 92.1, 92.2, 92.3 arranged in a second electric motor connector housing 91. The second electric motor connector housing 91 comprises further connection pins for connection with sixth connection pin holes in the second power board 40.

Further, the three second electric phase pins 92.1, 92.2, 92.3 comprise at ends opposite of the ends for connecting with corresponding electric motor pins (not shown) of the electric motor several second power board connection pins for electrically connecting these with the second power board 40. Further, the second electric motor connector housing 91 comprises second electric motor connector housing through holes for guiding bolts 1 therethrough for connection of the second power board 40 to the heat sink holes 56.1, 56.3 of the heat sink 50 by means of the second electric motor connector housing 91.

Further bolts 1 are guided through corresponding through holes in the second power board 40 for connection to the heat sink holes 56.2, 56.4 of the heat sink 50. Here, the second power board 40 is attached to the top side of the heat sink 50 with its bottom side. The second power board 40 also comprises second power board recesses 42.1, 42.2, 42.3 through which the first electric phase pins 82.1, 82.2, 82.3 of the first electric motor connector 80 are guided.

All bolts 1 are fastened such that the second power board 40 is fastened to the heat sink 50 and the heat sink 50 is fastened to the connector plate 10. The heat sink 50 is

thereby sandwiched in between the first power board 30 and the second power board 40. The logic board 20 is sandwiched in between the first power board 30 and the heat sink 50. The electric phase pins 82.1, 82.2, 82.3, 92.1, 92.2, 92.3 extend out of the second power board 40 and in particular beyond the heat sink projections 57.1, 57.2, 57.3 such that they may be connected with the electric motor pins of the electric motor. The venting element may be inserted into the venting opening 13 after inserting the electronic control unit 100 into the housing 210.

Figure 10 shows the process of inserting the electronic control unit 100 into the housing 210 of the electric power steering system 200. The heat sink projections 57.1, 57.2, 57.3 act as guides during this process.

Figure 11 shows a cross section through a part of the electric power steering system 200 having the housing 210. Therein, the housing 210 is not yet crimped into the groove 51 of the heat sink 50. However, the operation of crimping is indicated by an arrow referenced with the direction of force F of the crimping operation. Thereby, the housing 210 is plastically deformed and extends into the groove 51 of the heat sink 50. The heat sink 50 and the housing 210 thereby become attached to one another and thermally coupled.

Further, the circumferential outer surfaces 58.1, 58.2 of the heat sink 50 are attached to the inner surface 211 of the housing 210 for thermal coupling and allowing the heat sink 50 to dissipate heat generated by the two power boards 30, 40 attached to the heat sink 50 through the housing 210 into the environment. Also, the heat sink projections 58.1, 58.2, 58.3 may be arranged to rest on the inner rim 212 inside of the housing 210.

The housing 210 is further sealed by means of the circumferential sealing 12 of the connector plate 10 of the electronic control unit 100 against its inner surface 211. The connector plate 10 is thereby designed as a cap of the housing 210. Further, as can be seen in this cross section, the first electric phase pins 82.1, 82.2, 82.3 are to be

electrically connected to electric motor pins of the electric motor of the electric power steering system 200.

List of reference signs

10	Connector plate
11	Plug connector
12	Sealing
13	Venting opening
15	Signal connectors
16	Second power connector
17	First power connector
18	Dome
20	Logic board
21	First electronic component
30	First power board
31	Second electronic component
32	First power board recess
33	Power board through hole
40	Second power board
41	Third electronic component
42	Second power board recess
50	Heat sink
51	Groove
52	Heat conduction surface
53	Heat sink cutout
54	Heat sink through hole
55	Heat sink recess
56	Heat sink hole
57	Heat sink projection
58	Circumferential outer surface
59	Heat sink edge
60	Second logic connector
61	Second logic connector housing

70	First logic connector
71	First logic connector housing
80	First electric motor connector
81	First electric motor connector housing
82	First electric phase pin
90	Second electric motor connector
91	Second electric motor connector housing
92	Second electric phase pin
100	Electronic control unit
200	Electric power steering system
210	Housing
211	Inner surface
212	Inner rim
F	force

Electronic control unit and electric power steering system

Patent claims

1. Electronic control unit (100) for an electric power steering system (200), the electric power steering system (200) comprising a housing (210) and an electric motor, the electronic control unit (100) being configured to be arranged inside the housing (210) and to be electrically connected to the electric motor, whereby the electronic control unit (100) comprises at least one power board (30, 40) and a heat sink (50), the at least one power board (30, 40) being attached to the heat sink (50), and whereby at least one circumferential outer surface (58.1, 58.2) of a heat sink edge (59) of the heat sink (50) is in direct contact with an inner surface (211) of the housing (210) such that heat generated by the at least one power board (30, 40) is conducted via the heat sink (50) to the housing (210).
2. Electronic control unit (100) according to claim 1, whereby the heat sink (50) comprises a groove (51) arranged for crimping the housing (210) into the groove (51) and thereby securing the heat sink (50) with the housing (210).
3. Electronic control unit (100) according to claim 2, whereby the groove (51) is a circumferential groove (51) such that it is arranged around at least half of the circumference of the heat sink edge (59) of the heat sink (50), preferably around the entire circumference of the heat sink (50).
4. Electronic control unit (100) according to claim 2 or 3, whereby the groove (51) is arranged in between two circumferential outer surfaces (58.1, 58.2) of the heat sink edge (59) directly contacting the inner surface (211) of the housing (210).
5. Electronic control unit (100) according to any of claims 2 to 4, whereby the crimped housing (210) at the groove (51) is thermally connecting the heat sink (50) with the housing (210).
6. Electronic control unit (100) according to any of the previous claims, whereby the electronic control unit (100) comprises a first power board (30) and a

second power board (40) as the at least one power board (30, 40), the heat sink (50) being sandwiched in between the first power board (30) and the second power board (40).

7. Electronic control unit (100) according to claim 6, whereby electronic components (31) of the first power board (30) and electronic components (41) of the second power board (40) are facing towards the heat sink (50).
8. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) is configured as an at least partially circular heat plate.
9. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) comprises several heat conduction surfaces (52) arranged in contact with electronic components (31, 41) of the at least one power board (30, 40).
10. Electronic control unit (100) according to claim 8, whereby the several heat conduction surfaces (52) are arranged at different heights along a thickness of the heat sink (50) to accommodate electronic components (31, 41) of different height.
11. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) comprises heat sink through holes (54) and at least one power board (30) of the at least one power board (30, 40) is secured to the heat sink (50) by means of bolts (1) passing through the heat sink through holes (54) and being fastened in domes (18) extending from a connector plate (10) of the electronic control unit (100).
12. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) comprises heat sink holes (56) and at least one power board (40) of the at least one power board (30, 40) is secured to the heat sink (50) by means of bolts (1) being fastened in the heat sink holes (56).
13. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) comprises heat sink recesses (55) for second power connectors (16) of the electronic control unit (100), the second power connectors (16) extending from a connector plate (10) of the electronic control unit (100) through the heat sink recesses (55) inside of the heat sink

- (50) to at least one power board (40) of the at least one power board (30, 40).
14. Electronic control unit (100) according to any of the previous claims, whereby the heat sink (50) comprises a heat sink cutout (53), in particular extending from the heat sink edge (59) to an inside of the heat sink (50), a second logic connector (60) extending from a logic board (20) of the electronic control unit (100) through the heat sink cutout (53) to at least one power board (40) of the at least one power board (30, 40).
15. Electric power steering system (200) comprising the electronic control unit (100) according to any of the previous claims, whereby the electric motor of the electric power steering system (200) is electrically connected to the at least one power board (30, 40) by means of at least one electric motor connector (80, 90), and whereby the housing (210) of the electric power steering system (200) is crimped into the groove (51) of the heat sink (50) of the electronic control unit (100).

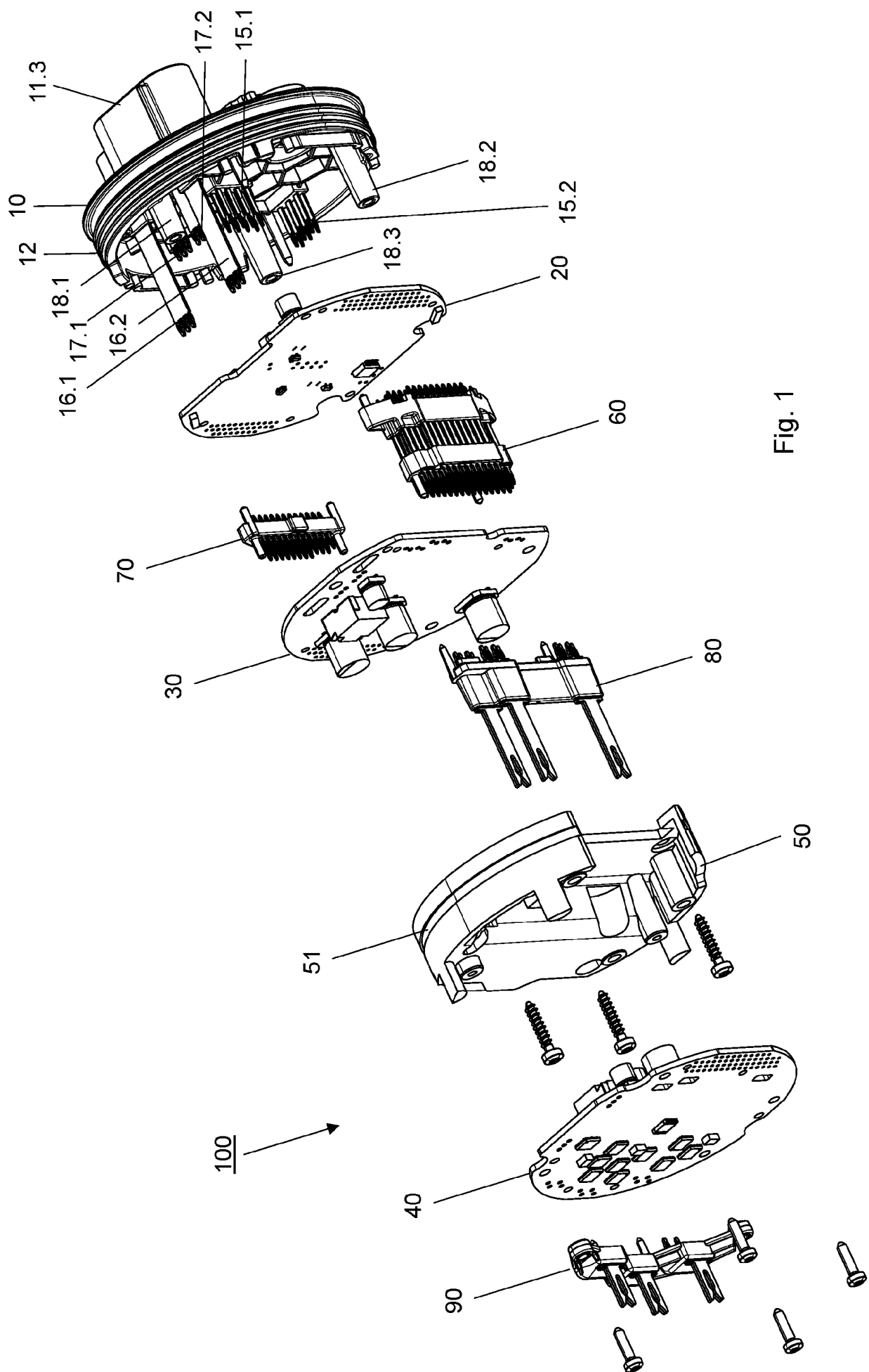


Fig. 1

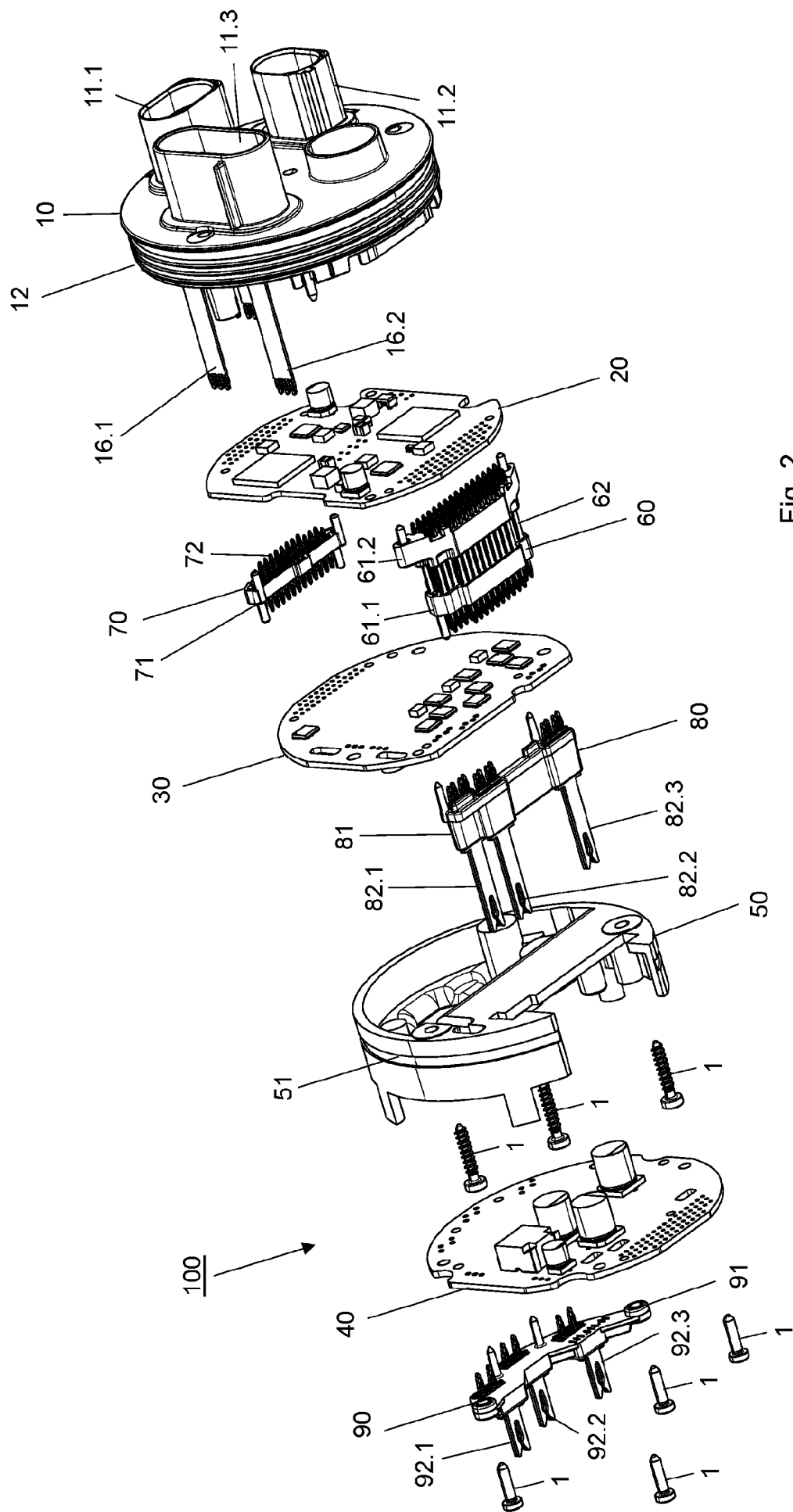


Fig. 2

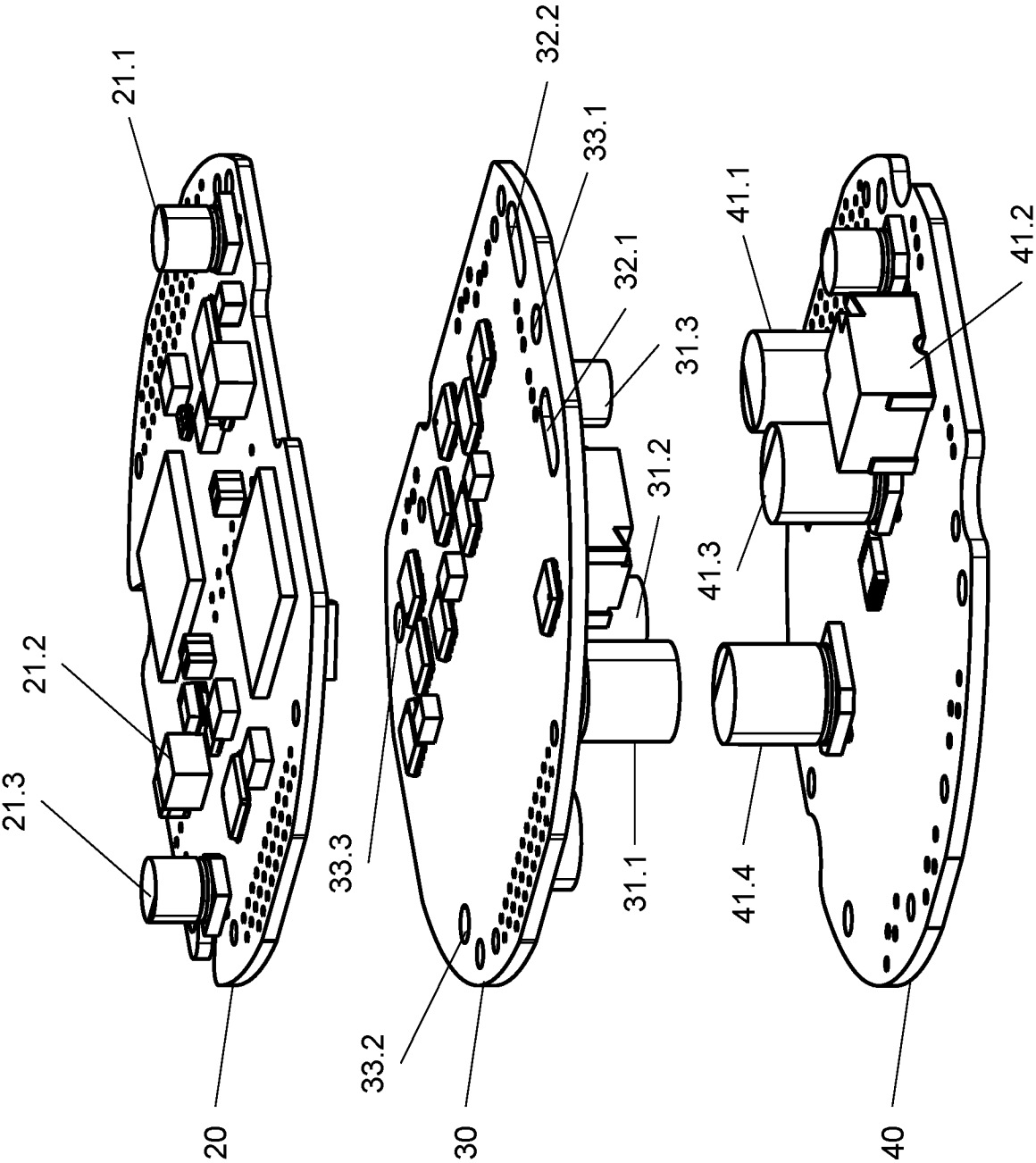


Fig. 3

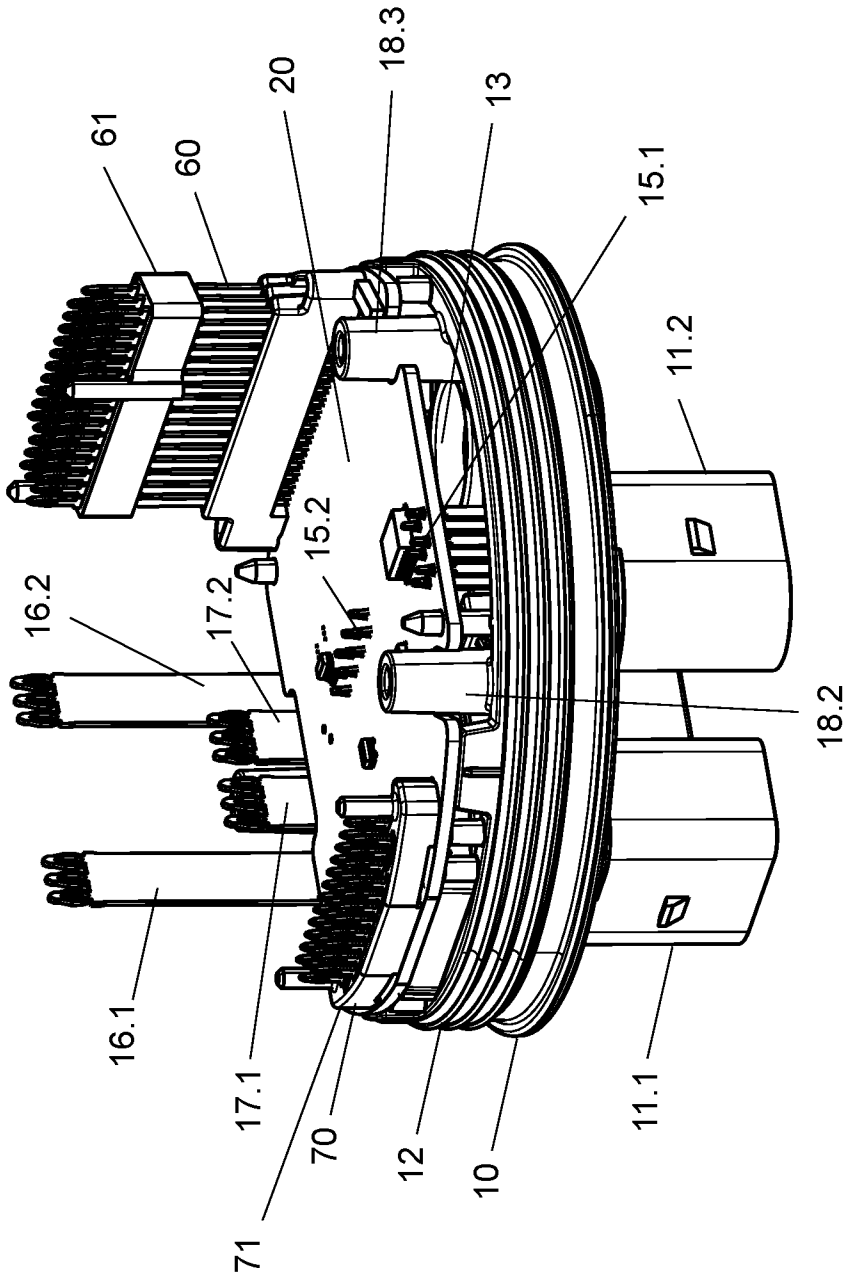


Fig. 4

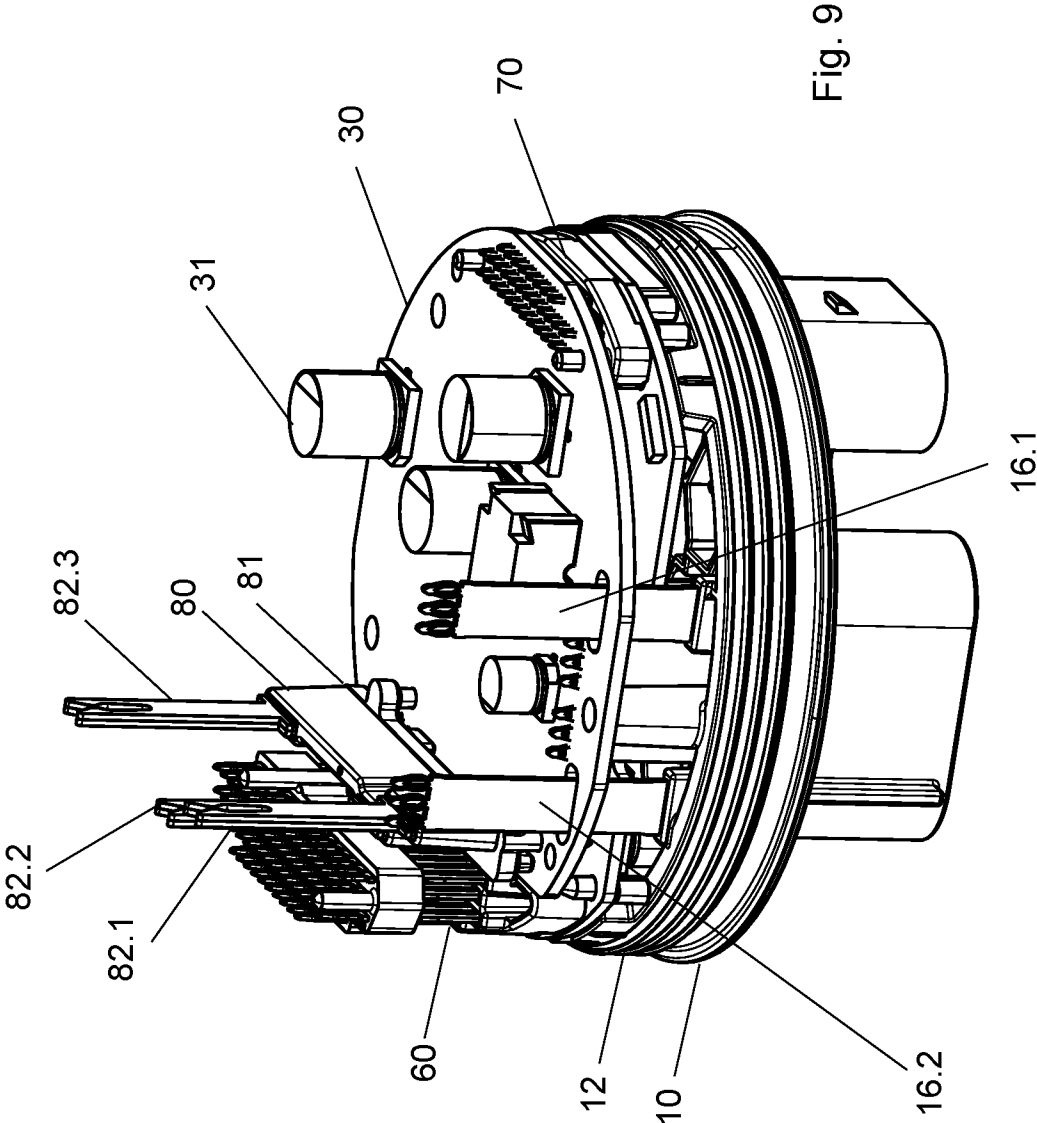


Fig. 5

Fig. 9

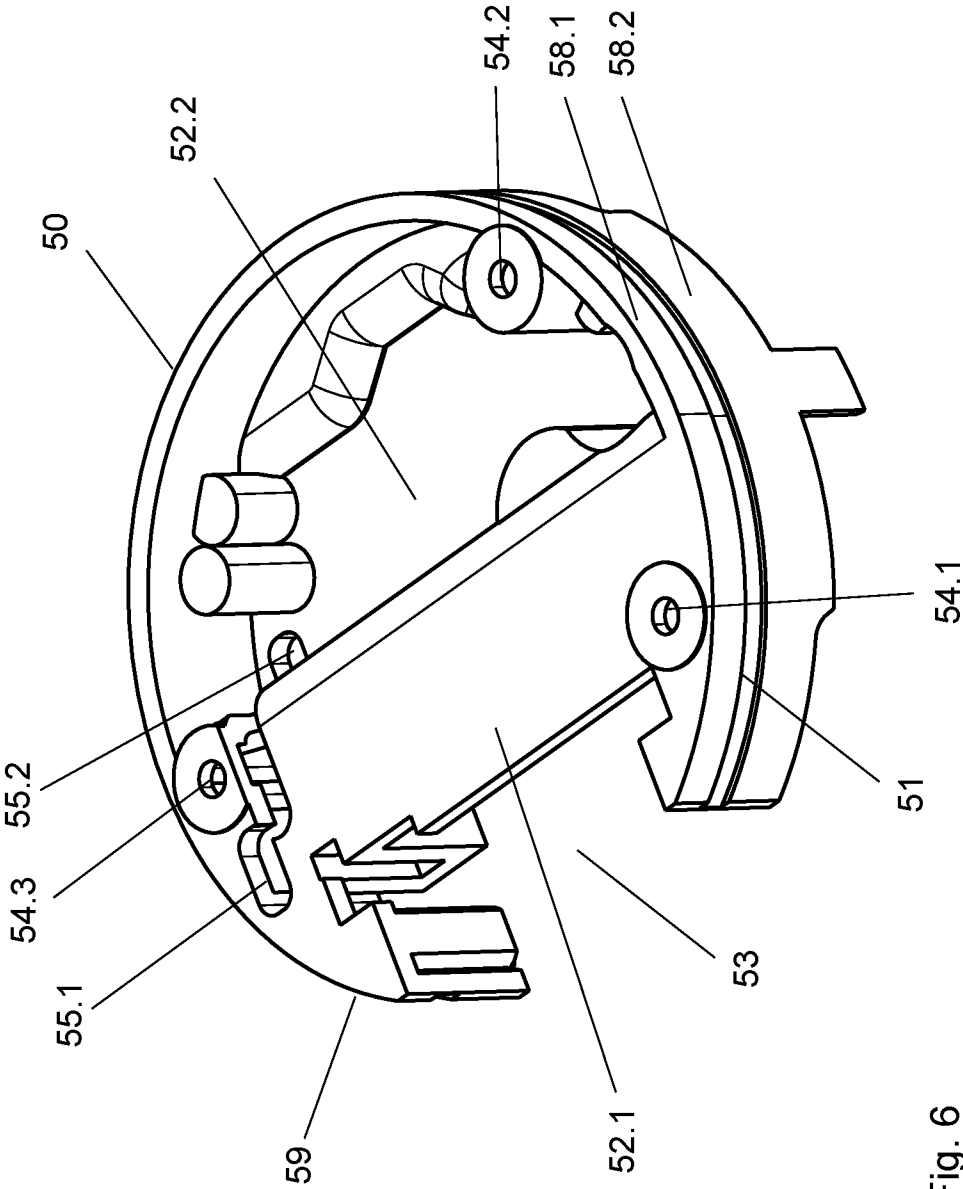


Fig. 6

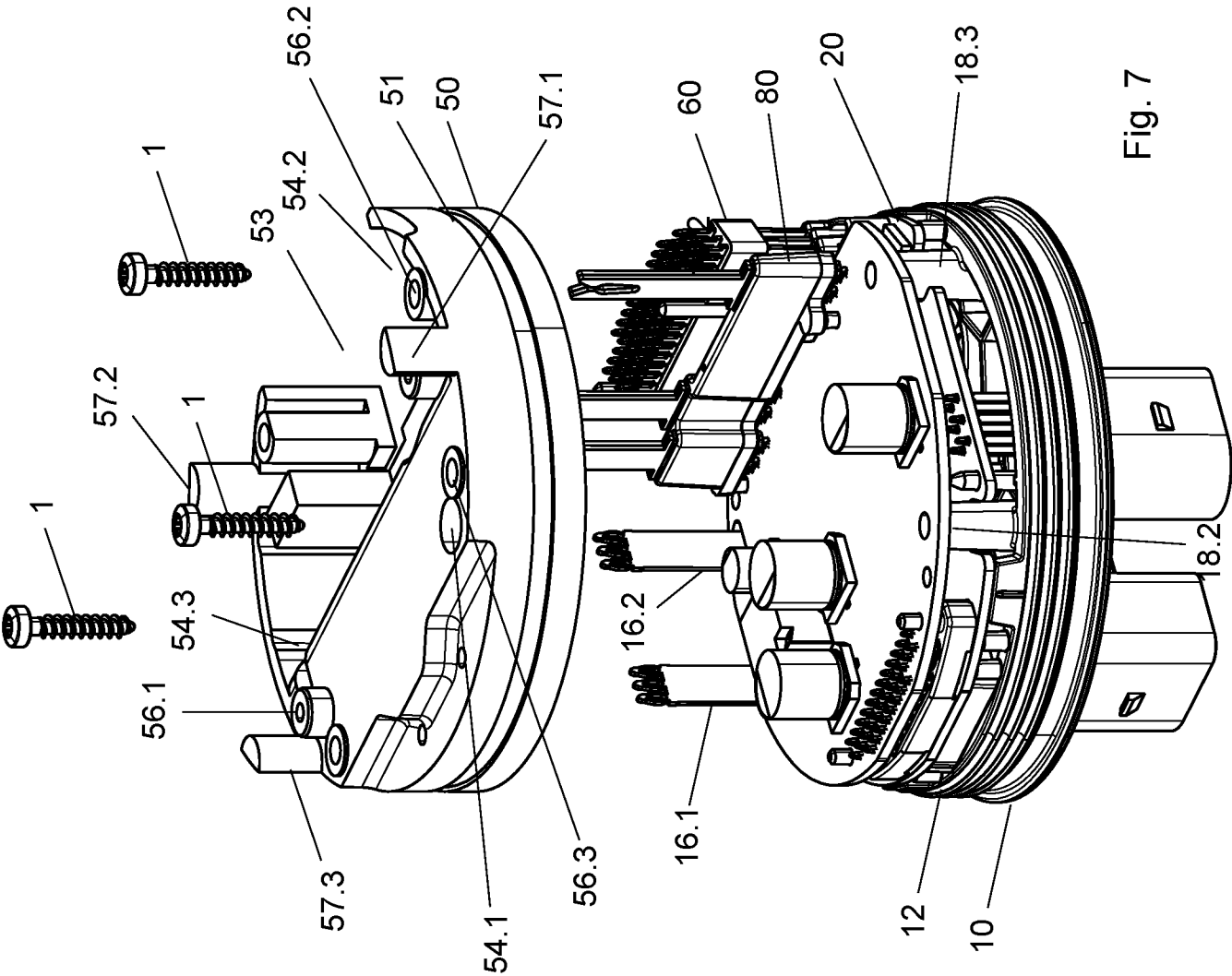
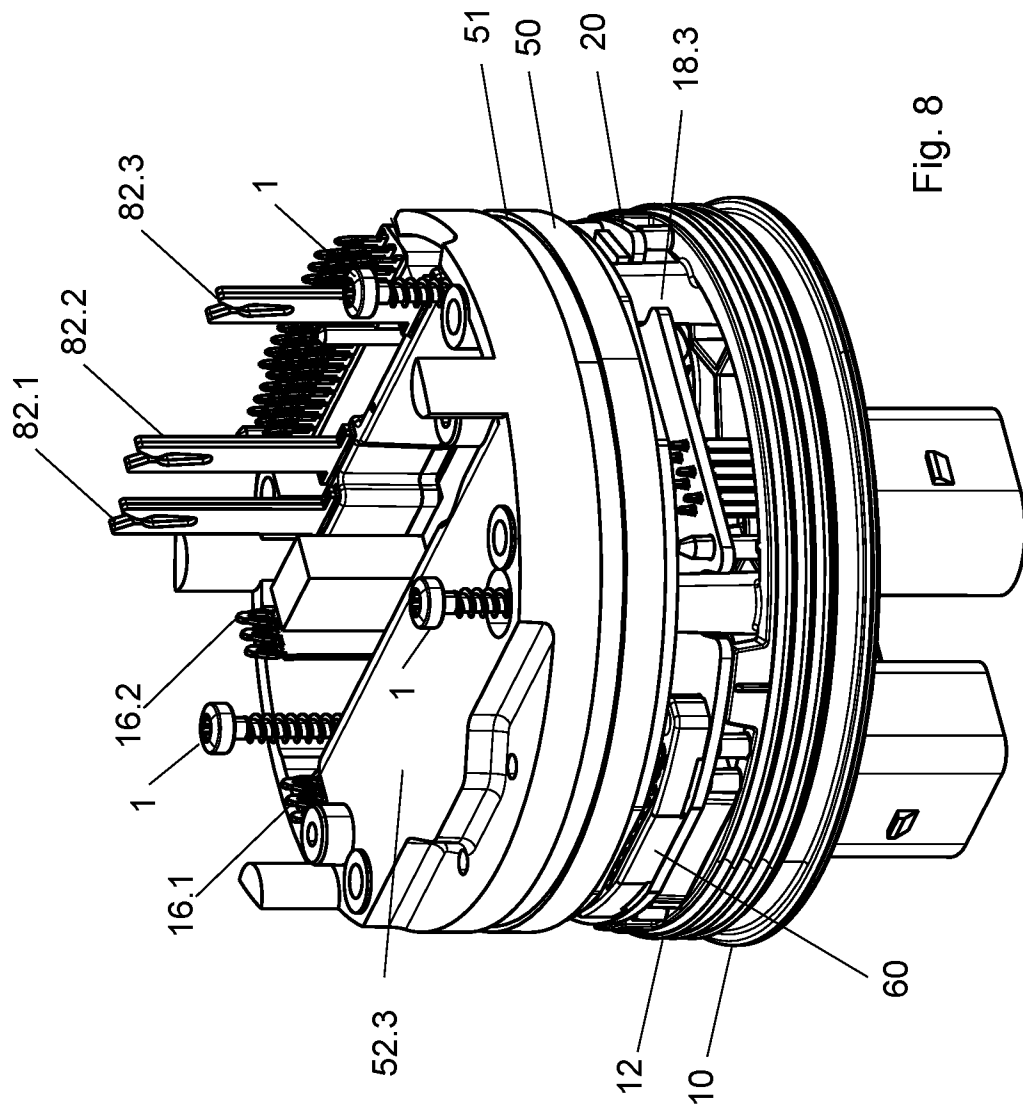


Fig. 7



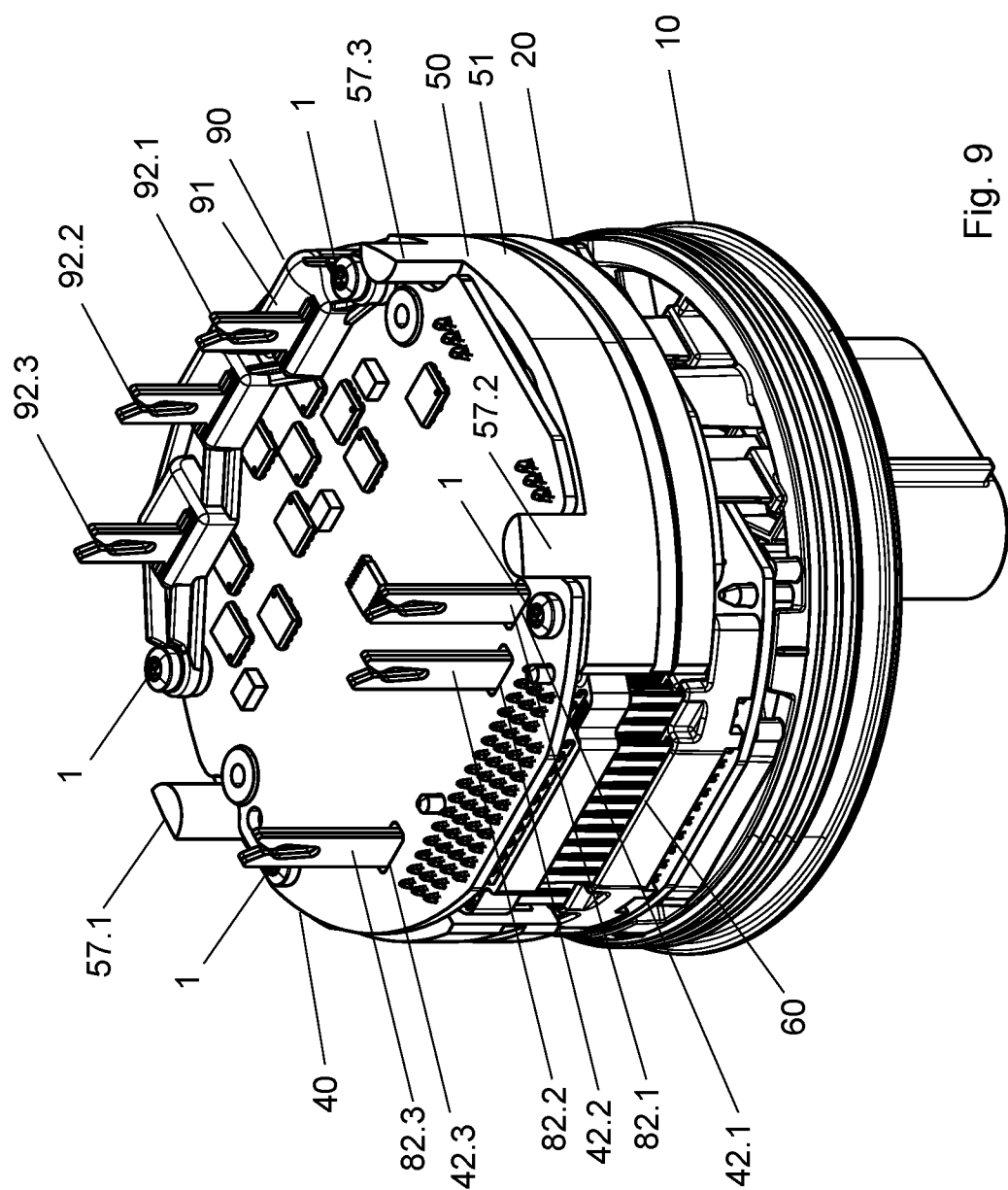
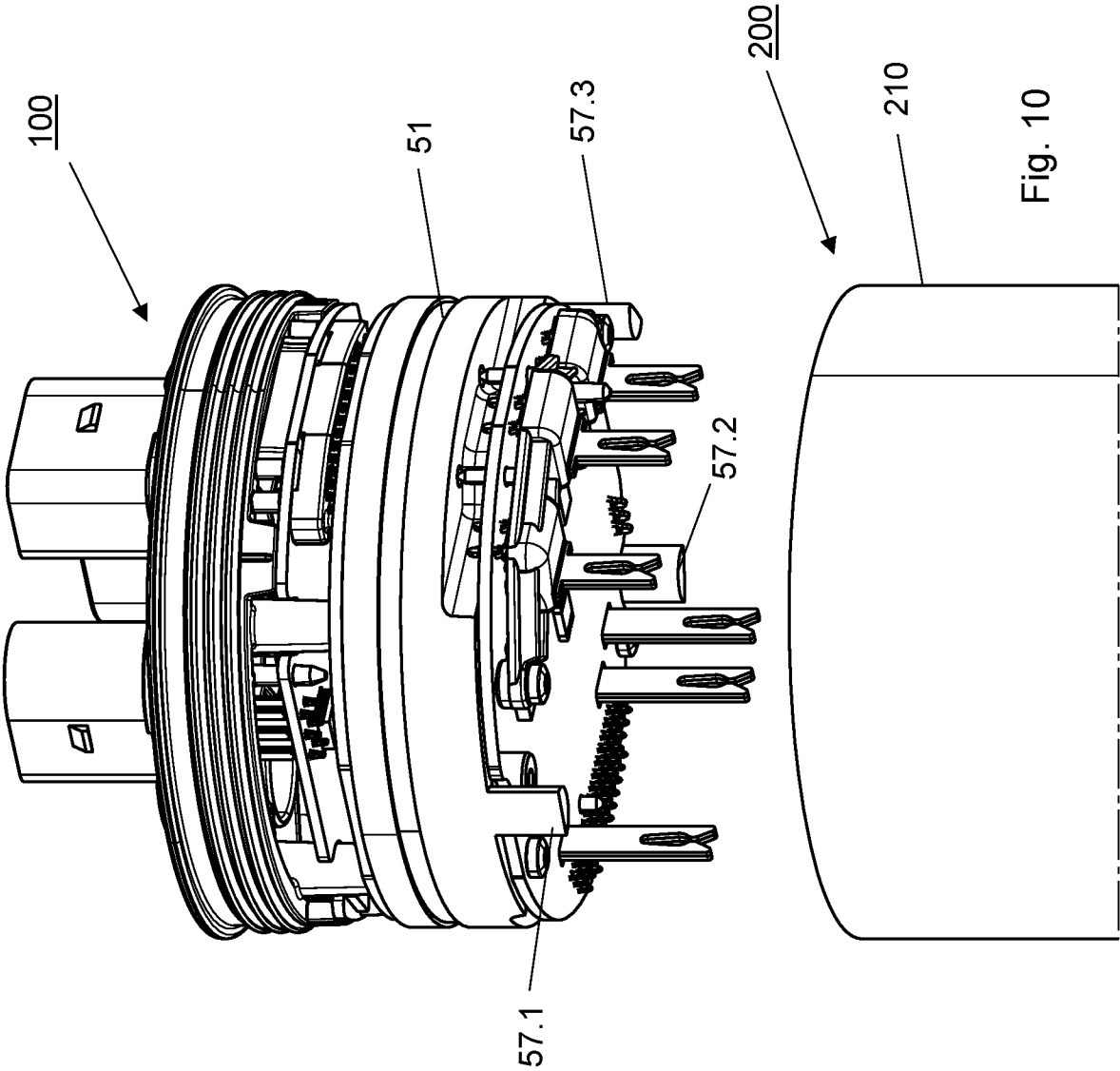


Fig. 9



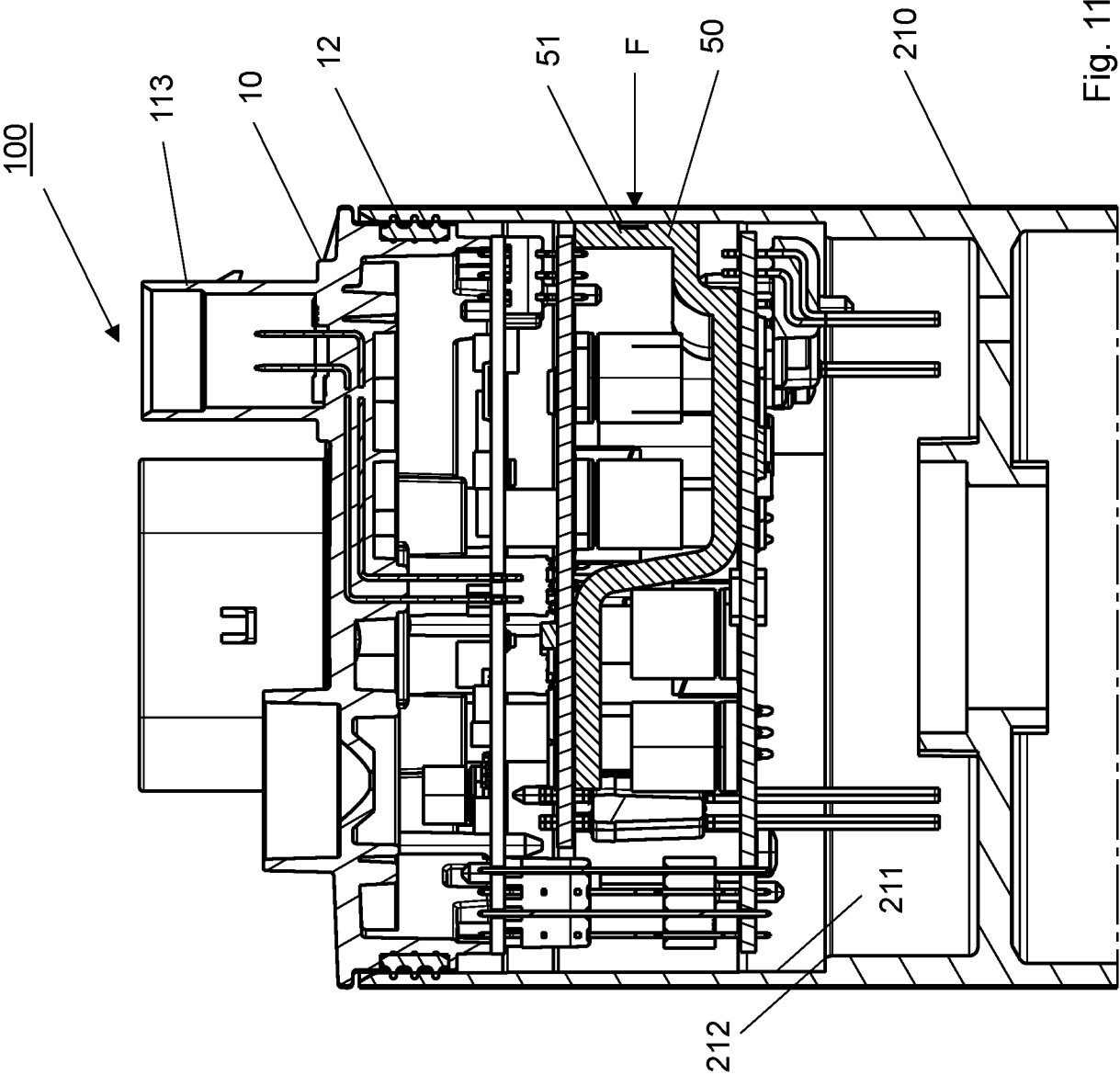


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/062851

A. CLASSIFICATION OF SUBJECT MATTER
INV. B62D5/04 H02K11/33
ADD. H02K5/22

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)
B62D H02K

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	US 2018/131256 A1 (FUJIMOTO MASAO [JP]) 10 May 2018 (2018-05-10)	1,6-12, 14
Y	paragraph [0042] - paragraph [0131]; figures 1-11	2-5,15
X	US 2017/349206 A1 (ASAO YOSHIHITO [JP] ET AL) 7 December 2017 (2017-12-07)	1,8,13
Y	paragraph [0020] - paragraph [0032]; figures 1-5	2-5
Y	US 2016/329781 A1 (ONISHI YOSHIHIKO [JP] ET AL) 10 November 2016 (2016-11-10)	2-5,15
	paragraph [0024] - paragraph [0058]; figures 1-7	
A	US 2019/351935 A1 (KIM JI HWAN [KR] ET AL) 21 November 2019 (2019-11-21)	1-15
	paragraph [0040] - paragraph [0047]; figures 1-8	



Further documents are listed in the continuation of Box C.



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

22 January 2021

Date of mailing of the international search report

01/02/2021

Name and mailing address of the ISA/

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

Authorized officer

Signorini, Luca

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/062851

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2018131256 A1	10-05-2018	CN 107408871 A DE 112016000624 T5 JP 6408926 B2 JP 2016144382 A KR 20170096204 A US 2018131256 A1 WO 2016125701 A1	28-11-2017 02-11-2017 17-10-2018 08-08-2016 23-08-2017 10-05-2018 11-08-2016
US 2017349206 A1	07-12-2017	CN 107249965 A EP 3260352 A1 JP 6366809 B2 JP WO2016132474 A1 US 2017349206 A1 WO 2016132474 A1	13-10-2017 27-12-2017 01-08-2018 01-06-2017 07-12-2017 25-08-2016
US 2016329781 A1	10-11-2016	CN 106464102 A EP 3145064 A1 JP 6095853 B2 JP WO2015173855 A1 US 2016329781 A1 WO 2015173855 A1	22-02-2017 22-03-2017 15-03-2017 20-04-2017 10-11-2016 19-11-2015
US 2019351935 A1	21-11-2019	CN 110492691 A DE 102019207025 A1 KR 20190130839 A US 2019351935 A1	22-11-2019 19-12-2019 25-11-2019 21-11-2019