US 20130257193A1

(19) United States

(12) Patent Application Publication

(10) Pub. No.: US 2013/0257193 A1

(43) Pub. Date: Oct. 3, 2013

TODA et al.

(54) **DRIVE APPARATUS AND METHOD FOR MANUFACTURING THE SAME**

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(21) Appl. No.: **13/853,469**

(22) Filed: **Mar. 29, 2013**

(30) **Foreign Application Priority Data**

Mar. 29, 2012 (JP) 2012-76142

Publication Classification

(51) **Int. Cl.**

H02K 5/10 (2006.01)
H02K 5/22 (2006.01)
H02K 15/00 (2006.01)
H02K 9/22 (2006.01)

(52) **U.S. Cl.**

CPC .. ***H02K 5/10*** (2013.01); ***H02K 9/22*** (2013.01); ***H02K 5/225*** (2013.01); ***H02K 15/00*** (2013.01)

USPC **310/52**; 29/596

(57) **ABSTRACT**

A motor drive apparatus includes a heat sink, on which a power module is disposed. A control circuit board and a power circuit board are disposed on axially opposite sides of the heat sink. A component carrier is disposed close to the power circuit board at a side opposite to an output part of a motor case. An electric connector is extended from the component carrier, passed through a hole of a cover and extended to an outside opposite to the output part. Even in a case where a mounting space is limited in a radial direction of the motor case, the electric connector can be easily connected to an external connector of a vehicle.

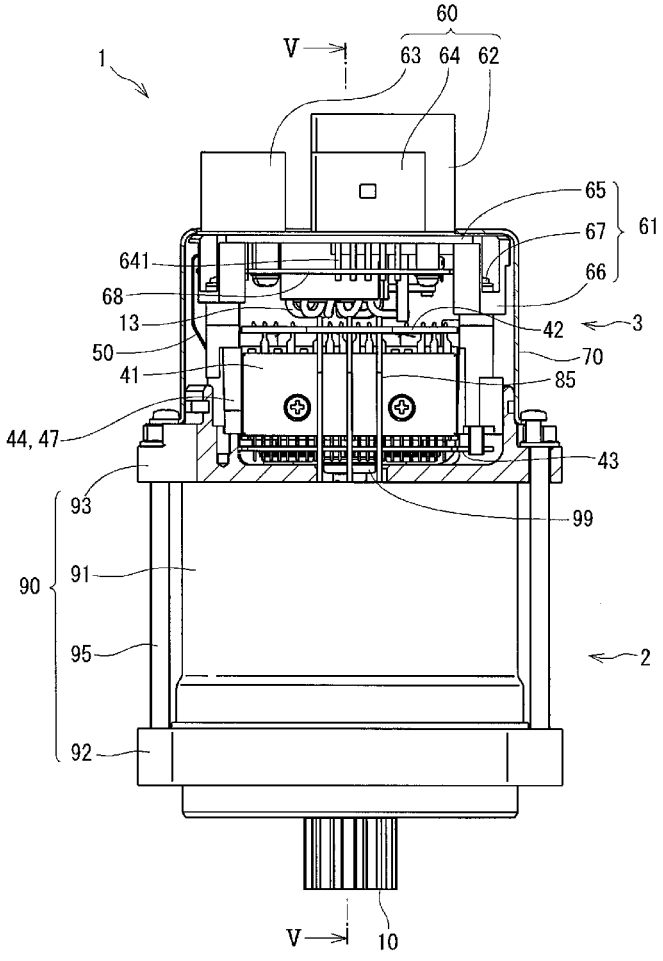


FIG. 1

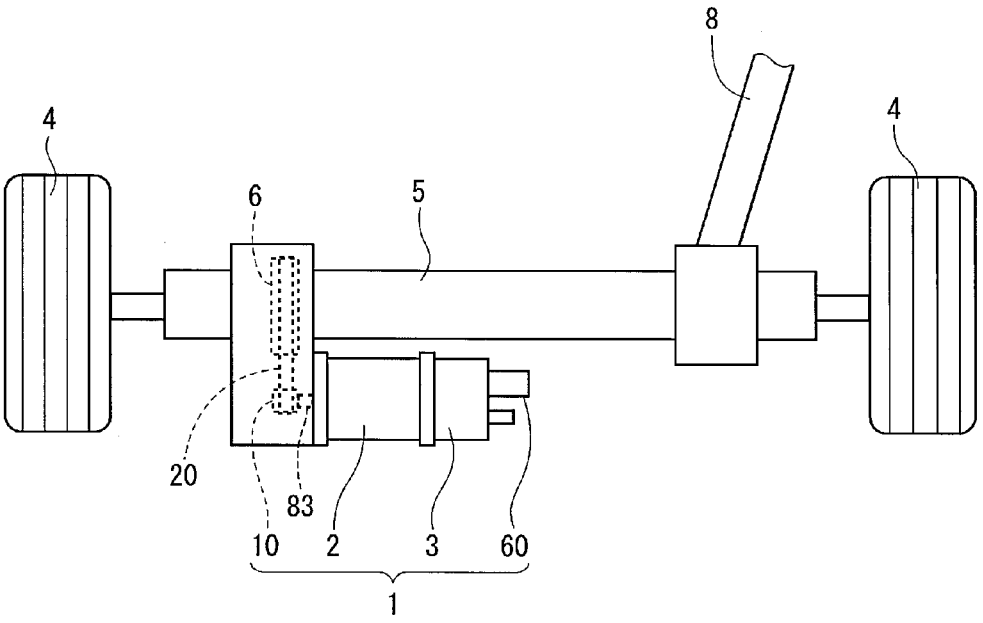


FIG. 2

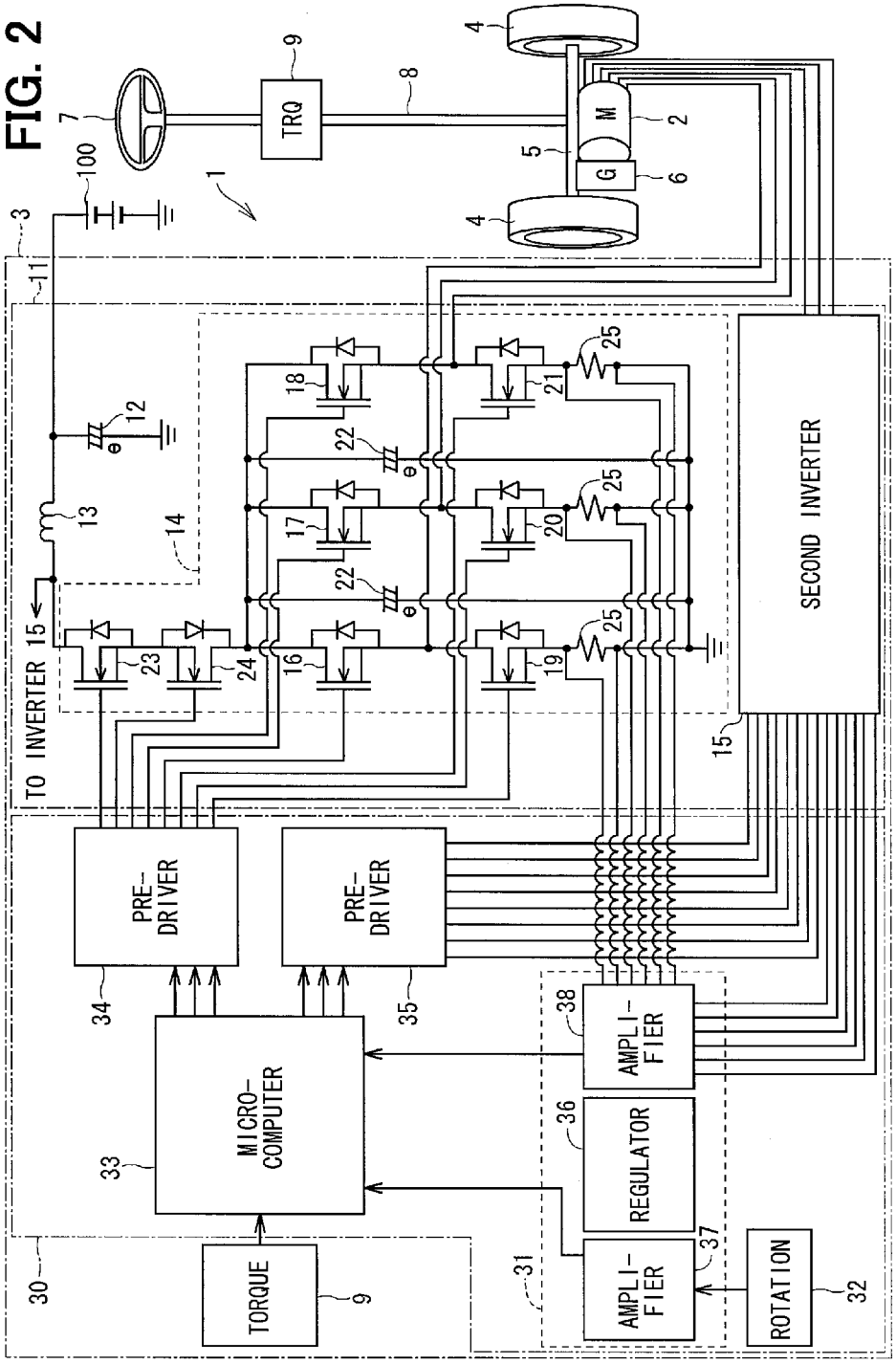
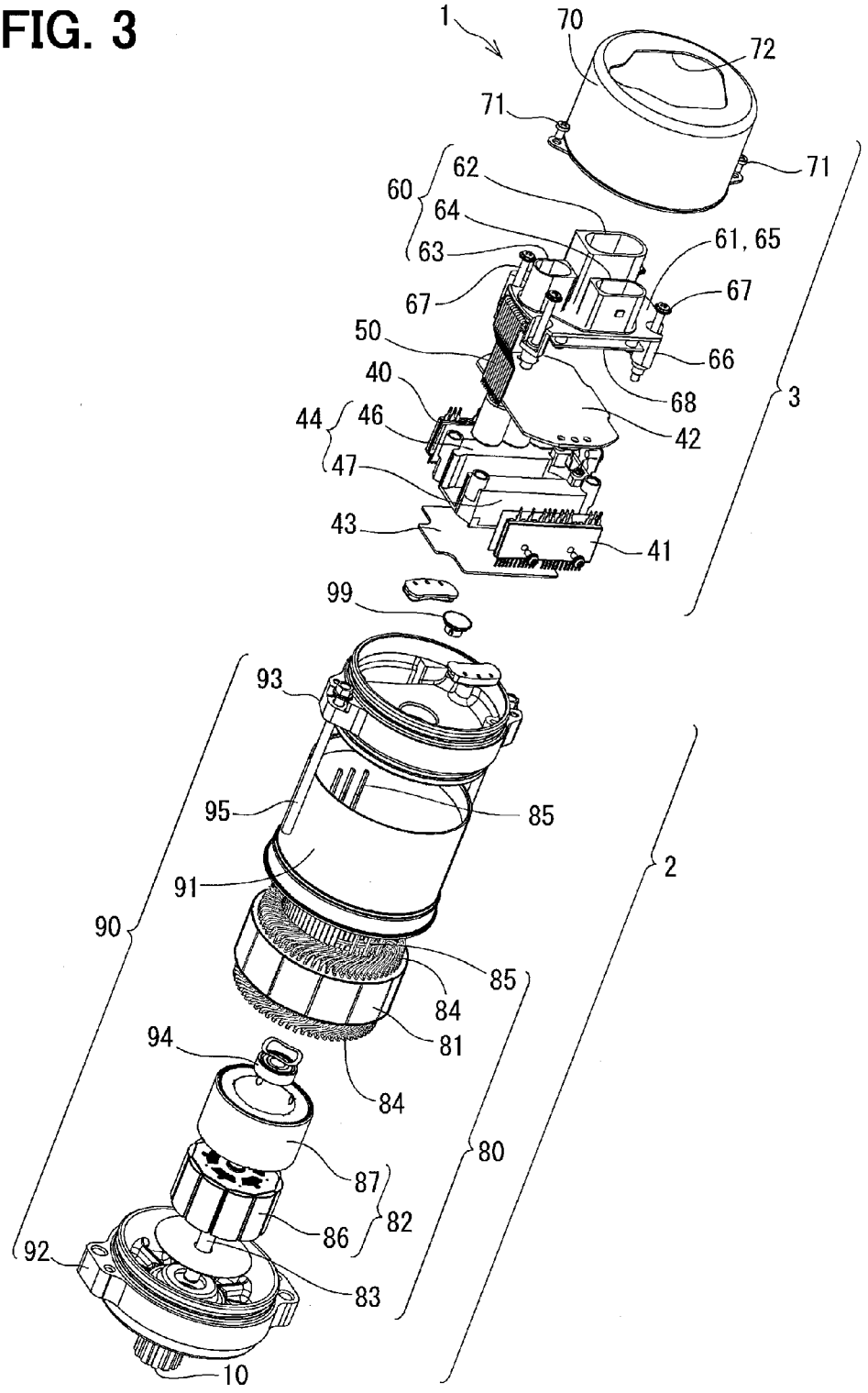

TRQ
M
G
SECOND INVERTER
TO INVERTER 15
PRE-DRIVER
PRE-DRIVER
MICRO-COMPUTER
AMPLI-FIER
REGULATOR
AMPLI-FIER
TORQUE
ROTATION

FIG. 3


1
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72
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60
64
63
61, 65
67
67
50
66
40
68
44
46
42
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43
41
3
99
93
95
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94
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82
86
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83
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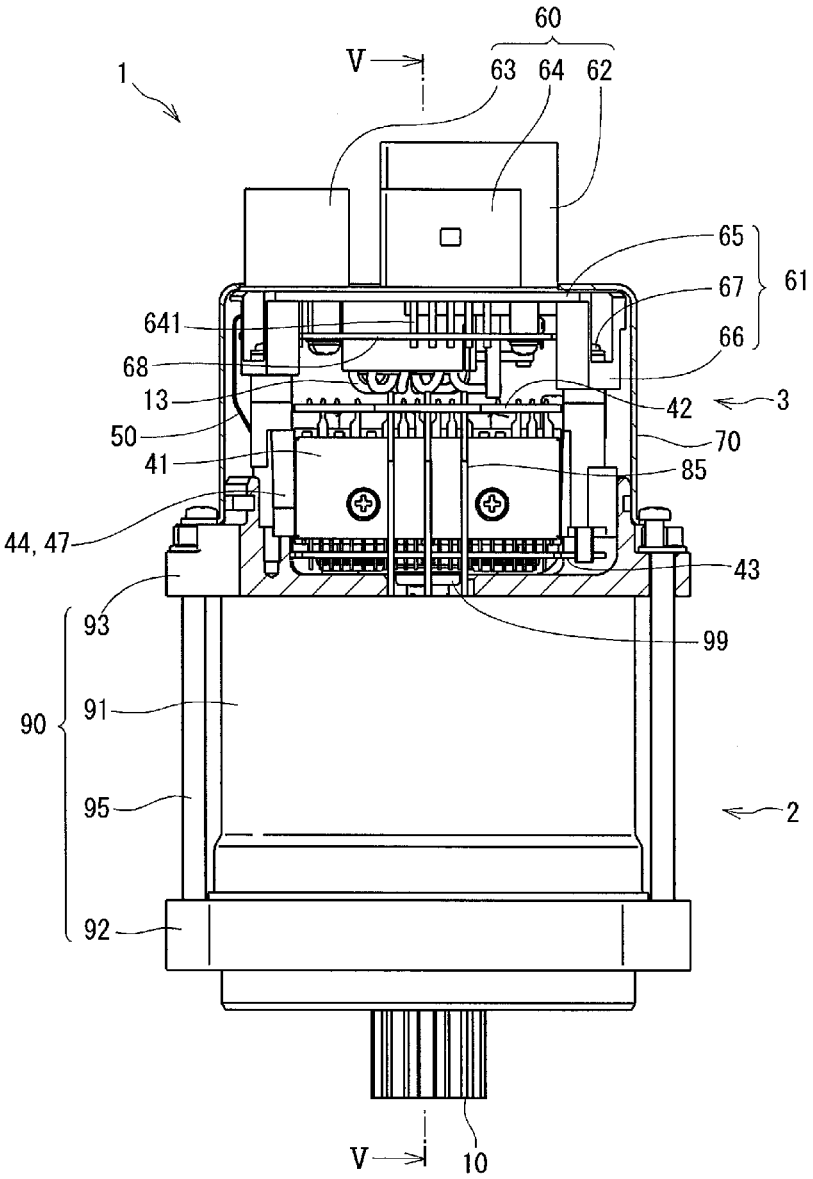
2

FIG. 4


60
V
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67
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641
66
68
13
42
3
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44, 47
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95
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V
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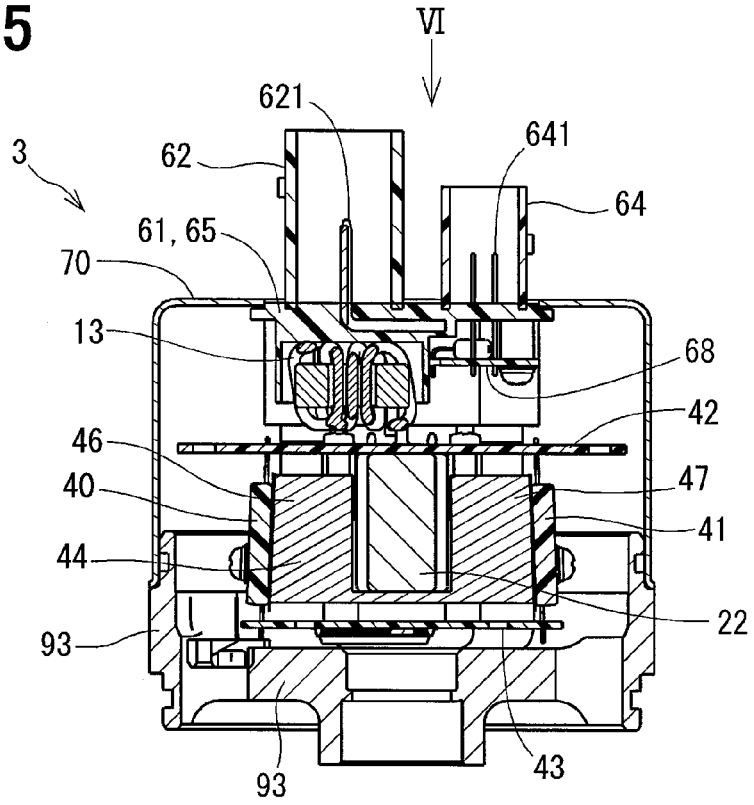
FIG. 5


VI
621
641
3
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61, 65
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44
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93
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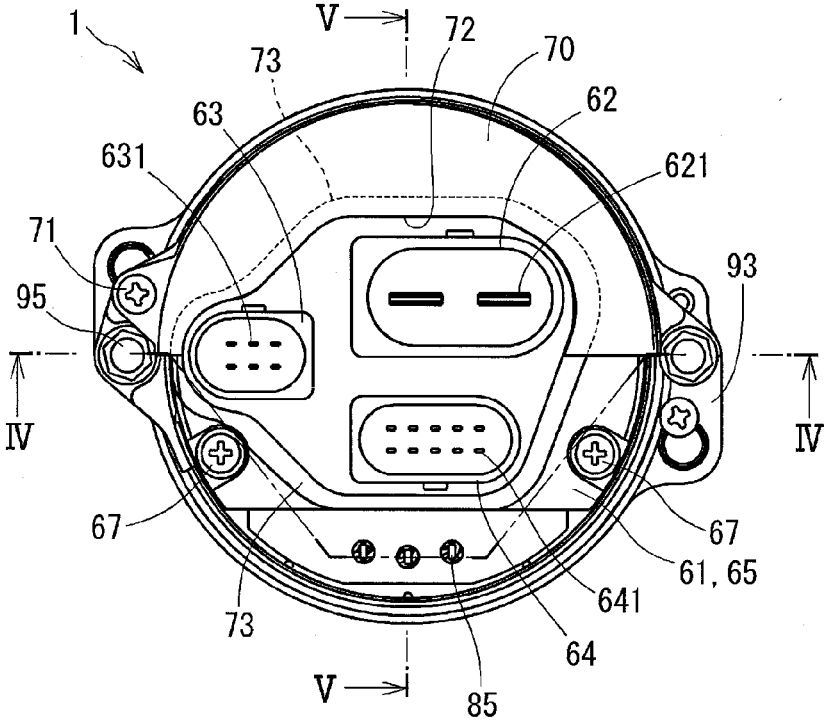
93

FIG. 6


1
V
72
70
73
62
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631
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93
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IV
IV
67
67
61, 65
641
73
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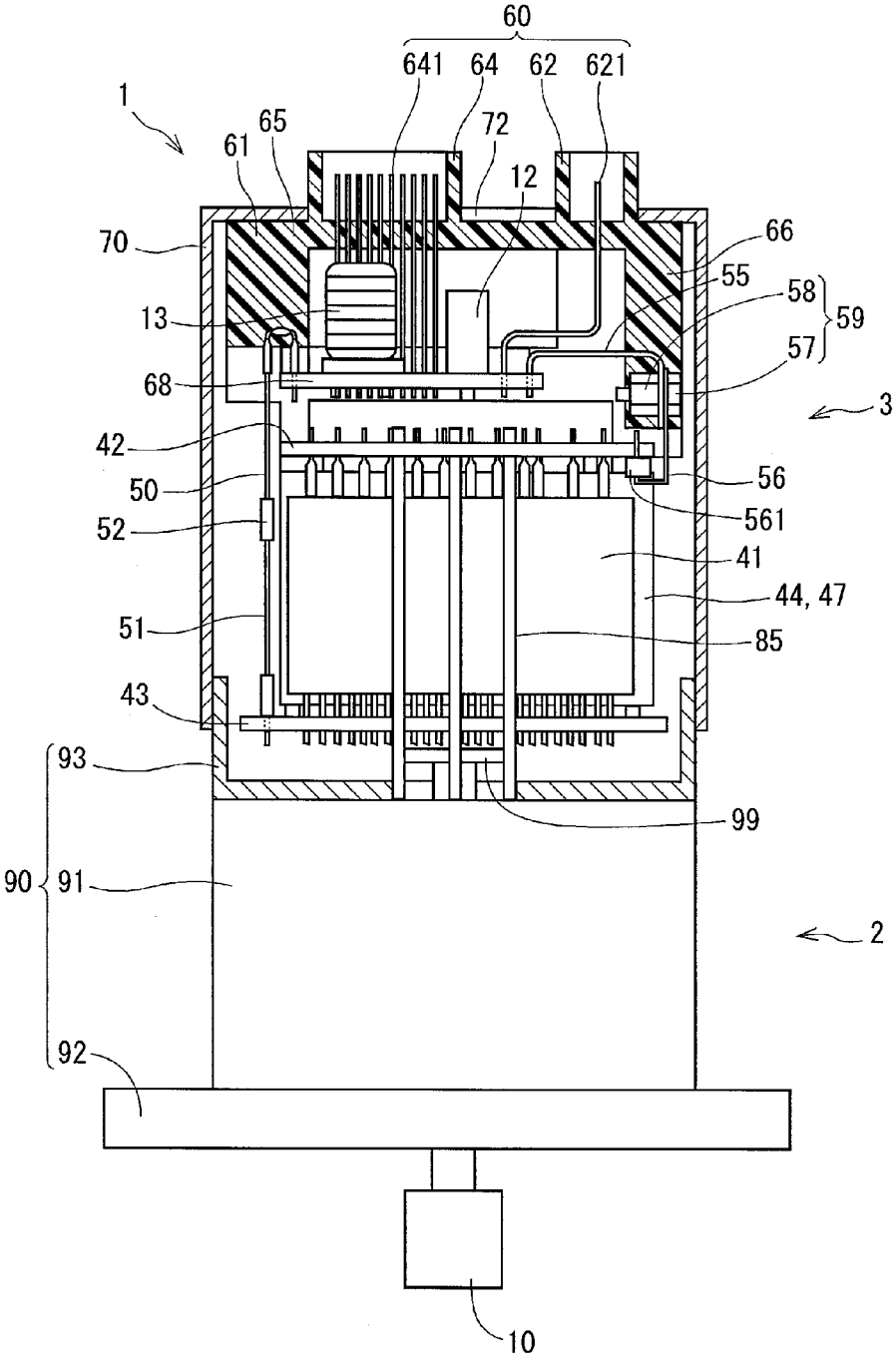
V
85

FIG. 7


60
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44, 47
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93
99
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91
2
92
10

FIG. 8

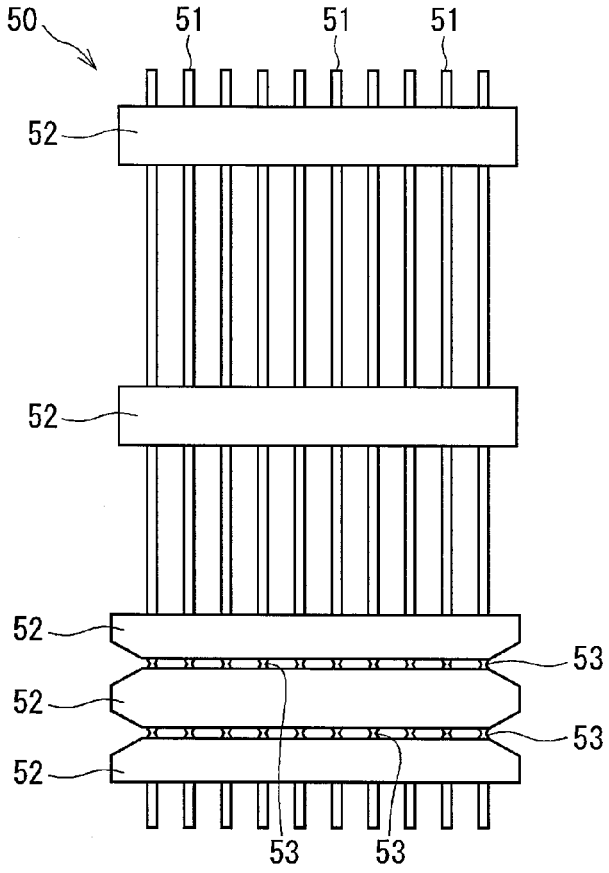

FIG. 9

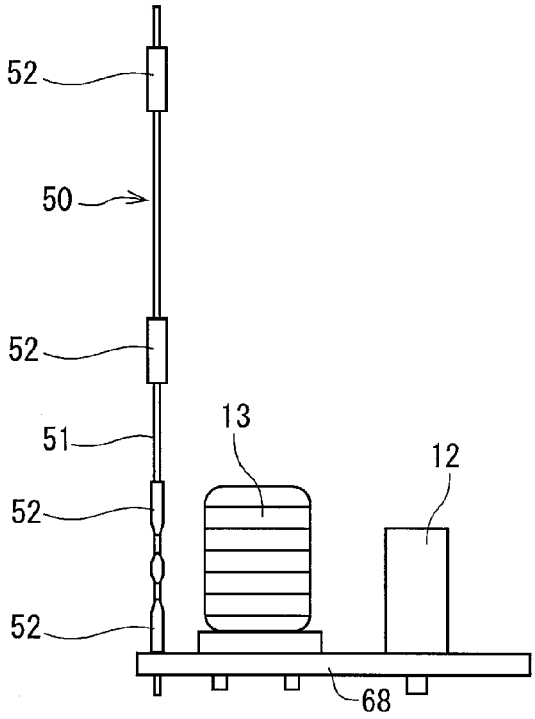

FIG. 10

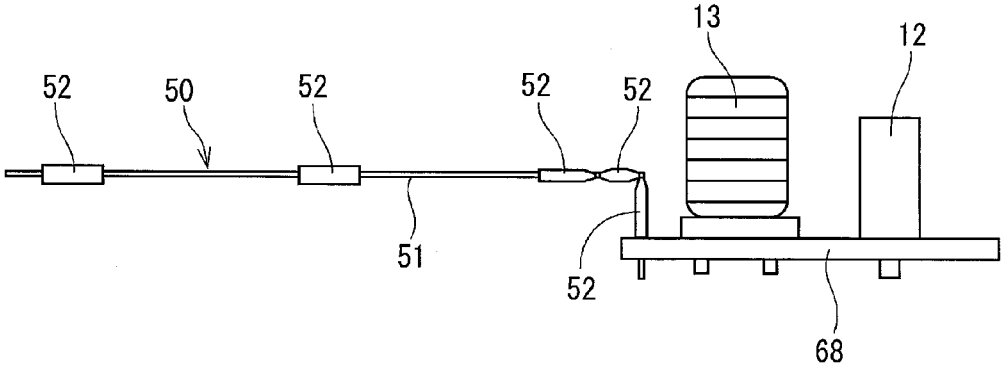

FIG. 11

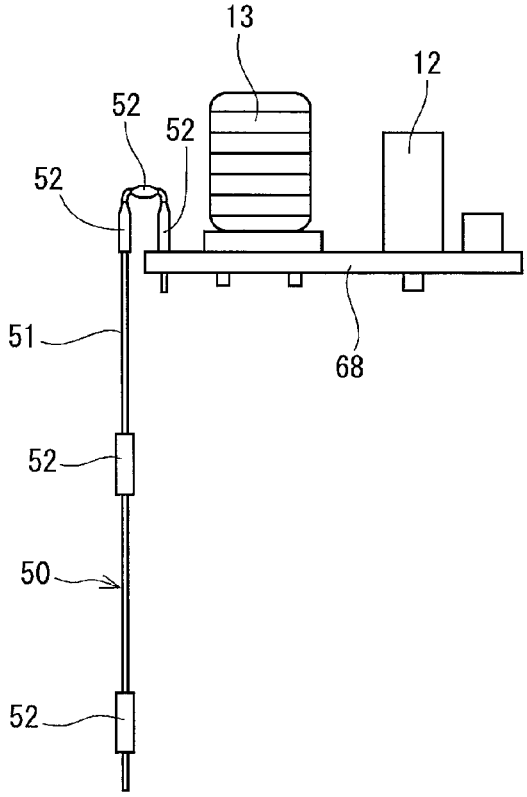

FIG. 12

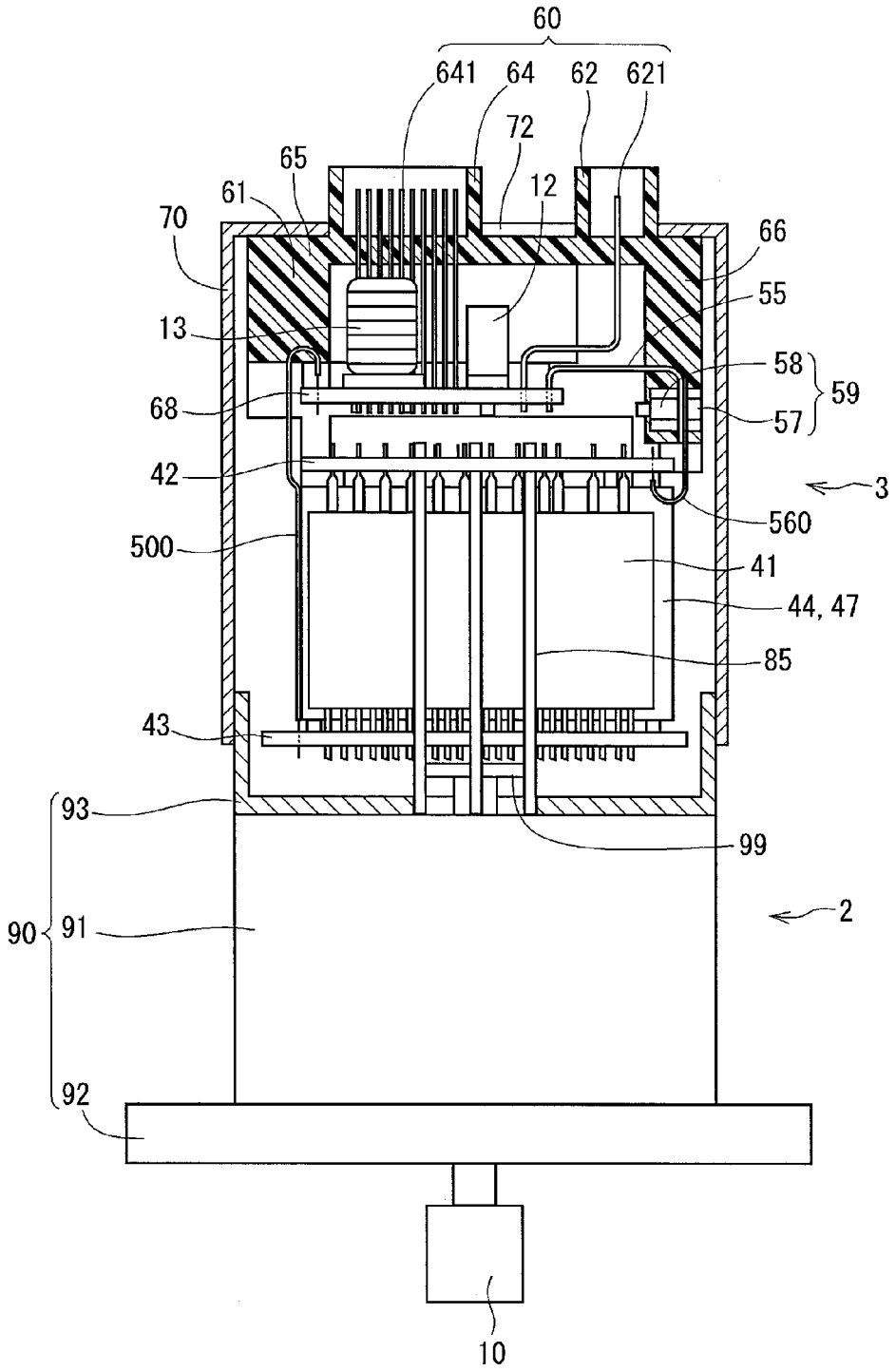
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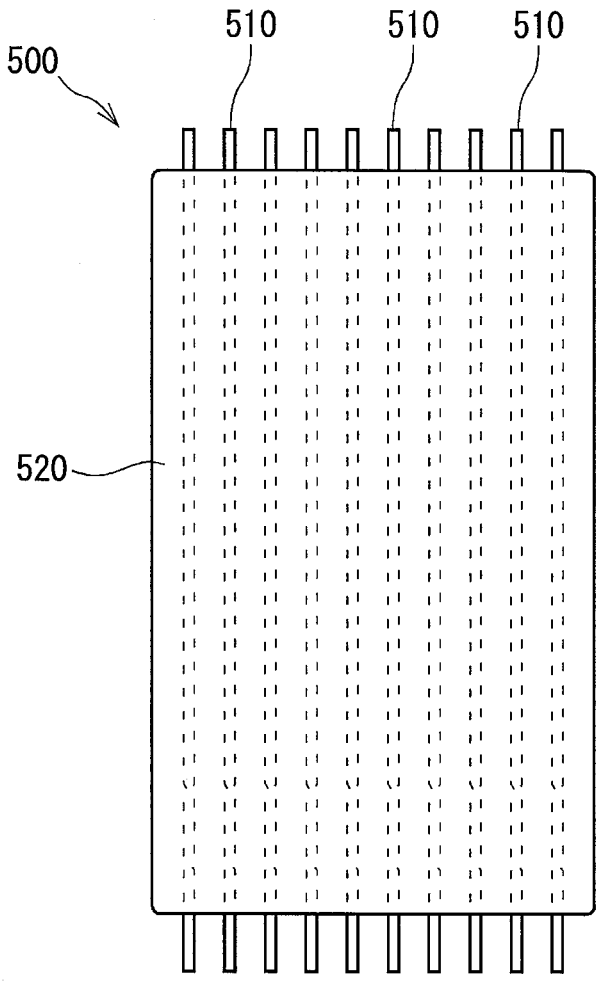
FIG. 13



DRIVE APPARATUS AND METHOD FOR MANUFACTURING THE SAME

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application is based on and incorporates herein by reference Japanese patent application No. 2012-76142 filed on Mar. 29, 2012.

TECHNICAL FIELD

[0002] The present disclosure relates to a motor drive apparatus, in which a motor is integrated with an electronic control unit and a method for manufacturing the same.

BACKGROUND

[0003] A conventional electric power steering system (EPS) assists a steering operation of a driver by driving force of a motor.

[0004] JP 2011-176998A (US 2012/0098361A1) discloses one exemplary motor drive apparatus applied to an EPS. The motor drive apparatus supplies torque to a speed reduction gear disposed on a column shaft coupled to a steering wheel of a vehicle to thereby assist a steering operation. In the motor drive apparatus, a connector disposed in a direction perpendicular to a motor shaft is connected to an external connector provided in the vehicle. An electronic control unit of the motor drive apparatus is supplied with electric current and a signal for driving the motor from the external connector provided in the vehicle via the connector of the motor drive apparatus.

[0005] The motor drive apparatus of the EPS is fixed to a rack for connecting left and right driving wheels of the vehicle in some cases. In this case, an engine is mounted above the rack, so that a space in which the motor drive apparatus is located is limited. For this reason, in the motor drive apparatus, a motor shaft is fixed parallel to a shaft of the rack.

[0006] The motor drive apparatus has a connector disposed in a direction perpendicular to a motor shaft. Hence, when the motor drive apparatus is fixed to the rack, it is difficult to connect the connector of the motor drive apparatus to the external connector of the vehicle.

[0007] Further, an engine compartment of a vehicle, in which the rack is arranged, is exposed to rain. Hence, when the motor drive apparatus is fixed to the rack, water or a foreign matter is likely to enter into a cover of the electronic control unit from a clearance between the cover and the connector.

SUMMARY

[0008] It is therefore an object to provide a motor drive apparatus, in which a connector is arranged on a side opposite to an output part of a motor, and a method for manufacturing the motor drive apparatus.

[0009] According to one aspect, a motor drive apparatus has a control circuit board arranged on an output part side in a motor shaft direction of a motor across a heat sink, and a power circuit board arranged on a side opposite to the output part. The motor drive apparatus includes a connector extended from a component carrier and passed through a hole of a cover and extended to a side opposite to the output part.

[0010] In this way, in the motor drive apparatus having a motor control unit which is small in dimension in a radial direction, the connector is disposed on the side opposite to the output part of the motor. For this reason, even in the case where a space, in which the motor drive apparatus is located, is limited in the radial direction of the motor shaft of the motor, the connector of the motor drive apparatus can be easily connected to an external connector of a vehicle. Hence, mounting work of the motor drive apparatus in the vehicle can be simplified.

[0011] A method for manufacturing a motor drive apparatus includes a first mounting step of inserting one end of a signal wiring into a connector board from a side of the connector and soldering the connector board and the signal wiring in a state where the signal wiring is raised perpendicularly with respect to the connector board, a bending step of bending the signal wiring to a side of the control circuit board, and a second mounting step of mounting the other end of the signal wiring on the control circuit board.

[0012] In this way, the signal wire can be easily mounted on the connector board and the control circuit board. Hence, a manufacturing cost can be reduced.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The above and other objects, features and advantages will become more apparent from the following detailed description made with reference to the accompanying drawings. In the drawings:

[0014] FIG. **1** is a schematic view of an EPS, to which a motor drive apparatus according to a first embodiment is applied;

[0015] FIG. **2** is a wiring diagram of the motor drive apparatus according to the first embodiment;

[0016] FIG. **3** is an exploded view, in perspective, of the motor drive apparatus according to the first embodiment;

[0017] FIG. **4** is a side view of the motor drive apparatus according to the first embodiment;

[0018] FIG. **5** is a cross-sectional view taken on a line V-V in FIG. **4** and showing only an electronic control unit part;

[0019] FIG. **6** is a top plan view taken in a direction in an arrow VI in FIG. **5** and an upper half shows a view with a cover disposed and a lower half shows a view with the cover removed.

[0020] FIG. **7** is a schematic cross-sectional view of the motor drive apparatus according to the first embodiment;

[0021] FIG. **8** is a plan view of signal wires of the motor drive apparatus according to the first embodiment;

[0022] FIG. **9** illustrates a method of fixing the signal wire of the motor drive apparatus according to the first embodiment;

[0023] FIG. **10** illustrates the method of fixing the signal wire of the motor drive apparatus of the first embodiment;

[0024] FIG. **11** illustrates the method of fixing the signal wire of the motor drive apparatus of the first embodiment;

[0025] FIG. **12** is a schematic cross-sectional view of a section of a motor drive apparatus of a second embodiment; and

[0026] FIG. **13** is a plan view of signal wires of the motor drive apparatus of the second embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] Hereinafter, a motor drive apparatus will be described in detail with reference to plural embodiments exemplarily shown in the drawings.

First Embodiment

[0028] Referring first to FIG. **1**, a motor drive apparatus **1** is applied to an electric power steering system (EPS) for assisting a steering operation of a driver by driving force of a motor unit **2**. The motor drive apparatus **1** is constructed of the motor unit **2** and an electronic control unit (ECU) **3**. The motor drive apparatus **1** is fixed to a rack **5** for connecting left and right tire wheels **4** of a vehicle in such a way that a motor shaft (rotary shaft) **83** of the motor drive apparatus **1** is parallel to a shaft of the rack **5**. In the motor drive apparatus **1**, an output part (output gear) of the motor shaft **83** of the motor unit **2** for outputting torque is coupled to a speed reduction gear **6** for moving the rack **5** in an axial or lateral (left and right) direction via a belt **20**.

[0029] When a steering wheel **7** is operated by the driver, torque produced in a steering shaft **8** by the steering operation is detected by a torque sensor **9** (FIG. **2**). The motor drive apparatus **1** produces torque for assisting the steering operation on the basis of a signal outputted from the torque sensor **9** and a vehicle speed signal transmitted from a CAN (control area network, not shown). This torque is transmitted to the rack **5** from the output part **10** of the motor drive apparatus **1** via the speed reduction gear **6** through the belt **20**.

[0030] In the motor drive apparatus **1**, an electric connector **60** disposed on a side opposite to the output part **10** has an external connector (not shown) of the vehicle connected thereto. An electric current and signals for driving the motor drive apparatus **1** are supplied to an electronic control unit **3** from the external connector of the vehicle via the electric connector **60** of the motor drive apparatus **1**.

[0031] As shown in FIG. **2**, the electronic control unit **3** is constructed of a power circuit **11**, through which an electric current for driving the motor unit **2** flows, and a control circuit **30** for controlling an operation of the power circuit **11**.

[0032] The power circuit **11** is constructed of a first capacitor **12**, a choke coil **13** and two inverters **14** and **15**. The inverter **14** is formed of a plurality of switching elements **16** to **21**, a plurality of second capacitors **22**, power relays **23**, **24** and a plurality of shunt resistors **25**. The inverter **15** also is formed similarly to the inverter **14**.

[0033] The power circuit **11** has an electric power supplied thereto from a DC power source **100**. The first capacitor **12** and the choke coil **13** provided in the power circuit **11** construct a filter circuit. Further, the choke coil **13** connected in series between the power source **100** and the power relays **23**, **24** attenuates a voltage variation.

[0034] Since the inverters **14** and **15** have the same configuration, one inverter **14** will be described in detail below.

[0035] The power relays **23**, **24** and the switching elements **16** to **21** are MOSFETs and are turned on or off between a source and a drain by a gate voltage. The power relays **23**, **24** are interposed between the switching elements **16** to **21** and the choke coil **13** and interrupts current flowing to the motor unit **2** through the switching elements **16** to **21** at the time of abnormality.

[0036] Three switching elements **16** to **18** on a power source side has their drains connected to a power source side and has their sources connected to drains of three switching elements **19** to **21** on a ground side corresponding to the respective three switching elements **16** to **18** on the power source side. The sources of the three switching elements **19** to **21** on the ground side are connected to the ground via the shunt resistors **25**. Connection points of the switching elements **16** to **18** on the power source side and the switching elements **19** to **21** on the ground side are connected to three-phase windings of the motor unit **2**, respectively.

[0037] The shunt resistors **25** are connected between the switching elements **19** to **21** and the ground, respectively. By detecting voltage or current applied to the shut resistor **25**, the current flowing through the motor unit **2** is detected.

[0038] The second capacitors **22** are connected to wiring on the power source side of the switching elements **16** to **21** and to wiring on the ground side. In short, the second capacitors **22** are connected in parallel to the switching elements **16** to **21**, respectively. The second capacitors **22** store electric charges to thereby assist power supply to the switching elements **16** to **21** and absorb ripple current produced when the current is switched.

[0039] The control circuit **30** is constructed of a custom IC **31**, a rotation angle sensor **32**, a microcomputer **33**, and pre-drivers **34** and **35**.

[0040] The custom IC **31** is an integrated circuit including a regulator **36**, a rotation angle sensor signal amplifier **37**, and a detection voltage amplifier **38**.

[0041] The regulator **36** is a stabilization circuit for stabilizing the electric power supplied from the power source **100**. The microcomputer **33** is operable with a given voltage (for example, 5V) regulated by the regulator **36**.

[0042] To the rotation angle sensor signal amplifier **37** is inputted a signal outputted from the rotation angle sensor **32**. The rotation angle sensor **32** is disposed in a magnetic field of a magnet disposed on the moor shaft **83** of the motor unit **2** and detects a change in the magnetic field. A signal outputted by the rotation angle sensor **32** is transmitted to the rotation angle sensor signal amplifier **37** as a signal relating to a rotation angle of a rotor of the motor unit **2**. The rotation angle sensor signal amplifier **37** amplifies the signal transmitted from the rotation angle sensor **32** and outputs the amplified signal to the microcomputer **33**.

[0043] The detection voltage amplifier **38** detects voltage between both ends of the shunt resistor **25** and amplifies a detected value and outputs the amplified value to the microcomputer **33**.

[0044] To the microcomputer **33** are inputted a signal of the rotation angle sensor signal amplifier **37**, a signal of the detection voltage amplifier **38**, a signal of the torque sensor **9**, and vehicle speed information from the CAN.

[0045] When these signals are inputted to the microcomputer **33**, the microcomputer **33** produces a pulse signal made by a PWM control via the pre-drivers **34** and **35** on the basis of the rotation angle of the rotor in such a way as to assist the steering operation of the steering wheel **7** according to the vehicle speed. The pulse signal controls a switching operation of turning on and off the switching elements **16** to **21** of the inverters **14**, **15** of two systems. Further, the microcomputer **33** controls the inverters **14**, **15** on the basis of the signal of the detection voltage amplifier **38** in such a way as to bring the current to be supplied to the motor unit **2** close to a sine wave. In this way, currents of sine waves having different phases are supplied to the motor unit **2**, whereby a rotating magnetic field is produced in the windings of a stator of the motor unit **2**. The motor unit **2** produces torque by the rotating magnetic field, whereby the steering operation by the driver can be assisted by the torque.

[0046] Next, the mechanical constructions of the motor unit **2** and the electronic control unit **3** will be described.

[0047] As shown in FIG. **3** and FIG. **4**, the motor unit **2** has a motor **80**, a motor case **90**, and the output part **10**. The motor **80** is constructed of a stator **81** and a rotor **82** including the motor shaft **83**.

[0048] The stator **81** has salient poles and slots arranged alternately in a circumferential direction. Coils **84** are received in the slots of the stator **81**. Each of the coils **84** is wound around each of the salient poles. The coils **84** form three-phase coil sets of two systems. Motor terminals **85** are led out from the coils **84**, extended to the electronic control unit **3** side and connected to a power circuit board **42**.

[0049] The rotor **82** is disposed in such a way as to rotate relatively to the stator **81** at a radially inside part of the stator **81**. The rotor **82** is provided with a rotor core **86**, which has different kinds of magnetic poles formed therein alternately in the circumferential direction, and a rotor case **87** for housing the rotor core **86**.

[0050] The motor shaft **83** is fixed at a rotation center of the rotor **82**. The motor shaft **83** has one end rotatably supported by a bearing (not shown) disposed at a front end frame **92** and has the other end rotatably supported by a bearing **94** disposed at a rear end frame **93**. At an end portion on a control circuit board side of the motor shaft **83** is disposed a magnet **99** for detecting a rotation angle of the rotor **82**.

[0051] The motor case **90** is constructed of a cylindrical motor case body **91**, the front end frame **92** and the rear end frame **93**. The stator **81** is fixed inside in the radial direction of the motor case body **91**. The motor case body **91** has one axial end fitted in the front end frame **92** via an O ring (not shown) and has the other axial end fitted in the rear end frame **93**. The front end frame **92** and the rear end frame **93** are fixed by through bolts **95** with the motor case body **91** interposed between them.

[0052] When current is passed through the coils **84** of the stator **81** from the switching elements **16** to **21** via the motor terminals **85**, a rotating magnetic field is formed and the rotor **82** and the motor shaft **83** are rotated normally or reversely with respect to the stator **81**. Torque is outputted to the speed reduction gear **6** of the rack **5** from the output part **10** disposed at a front end frame side of the motor shaft **83** via the belt **20**.

[0053] As shown in FIG. **3** to FIG. **7**, the electronic control unit **3** includes a heat sink **44**, a control circuit board **43**, a power circuit board **42**, the electric connector **60**, a component carrier **61**, and a cover **70**.

[0054] The heat sink **44** is formed of metal having a high thermal conductivity, for example, aluminum and is fixed to the rear end frame **93** at a side opposite to the output part **10**. The heat sink **44** has two side wall parts **46**, **47** disposed symmetrically across the motor shaft **83** of the motor **80**. One power module **40** is fixed to an outer wall of one wall part **46** and the other power module **41** is fixed to an outer wall of the other wall part **47**. The heat sink **44** can absorb heat generated by the two power modules **40** and **41**.

[0055] One power module **40** is constructed by the power supply relays **23**, **24**, the switching elements **16** to **21**, and the shunt resistors **25**, which form one inverter **14**, and wiring for connecting these components with a sealing body such as resin.

[0056] The other power module **41** is constructed by the switching elements and the like, which form the other inverter **15**, with a sealing body such as resin. The power module **40** is substantially the same as the power module **41**.

[0057] The power circuit board **42** is fixed to the heat sink **44** at a side opposite to the motor unit **2**. The power circuit board **42** is mounted with the first capacitor **12**, the choke coil **13**, and the second capacitor **22**, which construct the power circuit **11** described above. The second capacitor **22** is interposed between the two side wall parts **46** and **47**. The power circuit board **42** is provided with wirings which can pass the current supplied from the power source **100** of the vehicle via the electric connector **60** through the coils **84** of the motor unit **2** via the switching elements **16** to **21** and the second capacitor **22** which are included by the two power modules **40** and **41**.

[0058] The control circuit board **43** is fixed to a motor side of the heat sink **44**. The control circuit board **43** is mounted with the custom IC **31**, the rotation angle sensor **32**, the microcomputer **33**, and the pre-drivers **34** and **35**, which construct the control circuit **30**. In this way, the control circuit board **43** has the control circuit **30** constructed thereon. The control circuit **30** controls a switching operation of turning on and off the switching elements **16** to **21** of the two power modules **40** and **41** based on signals supplied to the electric connector **60** and the like.

[0059] The electric connector **60** and the component carrier **61** are integrally formed of resin such as PBT and are provided at a side opposite to the output part **10** when viewed from the heat sink **44**. The electric connector **60** is constructed of a power connector **62**, a sensor connector **63**, and a signal connector **64**. To a power source terminal **621** of the power connector **62** is supplied current for driving the motor **80**. To signal terminals **631** of the sensor connector **63** are supplied signals of the torque sensor **9** and the like. To signal terminals **641** of the signal connector **64** are supplied signals of CAN and the like.

[0060] In the case where the electric connector **60** and the power modules **40** and **41** are projected to an imaginary plane perpendicular to the motor shaft **83**, a part or all of the power connector **62**, the sensor connector **63**, and the signal connector **64** are positioned between the power modules **40** and **41**.

[0061] The component carrier **61** has a plate **65**, which is nearly shaped like a rectangle and is extended nearly perpendicularly to the motor shaft **83** of the motor **80**, and four legs **66** which are extended to the heat sink **44** side from corner portions of the rectangle of the plate **65**. Bolts **67** are inserted into holes formed in the axial direction of the legs **66**. The bolts **67** are passed through the holes formed in the axial direction of the heat sink **44** and are screwed in female threads formed in the rear end frame **93**. In this way, the component carrier **61**, the heat sink **44**, and the rear end frame **93** are fixed one another.

[0062] The cover **70** is formed in the shape of a cylinder having a closed bottom and houses the heat sink **44**, the control circuit board **43**, the power circuit board **42**, and the component carrier **61**. The cover **70** is fixed to the rear end frame **93** by screws **71**.

[0063] The cover **70** has a hole **72**, through which the electric connector **60** is passed, formed on a side opposite to the output part **10**. The electric connector **60** is passed through the hole **72** from inside of the cover **70** and is extended to the side opposite to the output part **10**.

[0064] A sealing member **73** is disposed between the plate **65** of the component carrier **61** and the cover **70** in such a way as to surround a radial outside of the hole **72** of the cover **70**. In FIG. **6**, position in which the sealing member **73** is disposed is shown by a broken line and a solid line. The sealing member **73** is a liquid gasket such as FIPG (formed in place gasket). The sealing member **73** is applied in a liquid state on the plate **65** of the component carrier **61** or on an inner wall of

the cover **70** before the cover **70** is fixed to the rear end frame **93**. Then, when the cover **70** is fixed to the component carrier **61** by the screws **71**, the sealing member **73** is put into close contact between the cover **70** and the component carrier **61**.

[0065] The component carrier **61** is provided with a connector board **68**. In this regard, the choke coil **13** and the first capacitor **12** may be fixed to the power circuit board **42** or the component carrier **61** or may be mounted on the connector board **68** as shown in FIG. **7**.

[0066] The connector board **68** has the power source terminal **621** of the power connector **62**, signal terminals **631** of the sensor connector **63**, and signal terminals **641** of the signal connector **64** connected thereto. The connector board **68** is a multilayer board in which wiring connected to the power source terminal **621** and the signal terminals **631**, **641** are laminated. The wirings connected to the signal terminals **631**, **641** or to the power source terminal **621** are laid on the connector board **68** and are arranged at a position, at which a signal wiring **50** or a connection terminal **55** is suitably connected.

[0067] The signal wiring **50** electrically connects a control circuit of the control circuit board **43** to the connector board **68**. When viewed from a direction of the motor shaft **83** of the motor **80**, the signal wiring **50** is positioned in a direction perpendicular to a direction in which the one power module **40** is opposed to the other power module **41**.

[0068] In FIG. **8** is shown the signal wiring **50**, which is not yet fixed to the electronic control unit **3**.

[0069] The signal wiring **50** has a plurality of terminals **51** arranged in parallel and resin molds **52** for integrally molding the plurality of terminals **51**. Each of the resin molds **52** extends perpendicularly to the terminals **51** and molds the plurality of terminals **51** in such a way that the plurality of terminals **51** except for bent portions, in which the plurality of terminals **51** are o be bent, are integrated with each other. The plurality of terminals **51** has cutout portions **53**, in which bent portions are small in thickness to be bent with less force.

[0070] As shown in FIG. **7**, the power source terminal **621** of the power connector **62** is mounted on the connector board **68**. Further, the power circuit board **42** has the connection terminal **55** mounted thereon. The connection terminal **55** is electrically connected to the power source terminal **621** via the choke coil **13** and the first capacitor **12**. The connection terminal **55** has an end portion on a side opposite to the power circuit board **42** molded by the component carrier **61**.

[0071] On the other hand, the power circuit board **42** has two power wirings **56** mounted thereon, the two power wirings **56** corresponding to the power source **100** and the ground. The two power wirings **56** are integrally molded with resin **561**. The connection terminal **55** and the power wirings **56** have holes (not shown) formed therein. When a bolt **57** is inserted into the holes of the connection terminal **55** and the power wirings **56** and a nut **58** is screwed on the bolt **57**, the connection terminal **55** is electrically connected to the power wirings **56**. A connection portion **59**, in which the connection terminal **55** is connected to the power wirings **56**, is supported by the component carrier **61**. In this way, the bolt **57** can be easily screwed with the nut **58**, that is, the connection terminal **55** can be easily connected to the power wirings **56**. Here, the connection terminal **55** may be connected to the power wirings **56** by welding.

[0072] Next, a method for fixing the signal wiring **50** in relation to a method for manufacturing the motor drive apparatus **1** will be described with reference to FIG. **9** to FIG. **11**. The method for fixing the signal wiring **50** includes a first mounting step, a bending step, and a second mounting step.

[0073] As shown in FIG. **9**, in the first mounting step, one ends of the terminals **51** of the signal wiring **50**, leads of the choke coil **13**, and leads of the first capacitors **12** are inserted into through holes of the connector board **68** from one direction. The signal wiring **50** has the plurality of terminals **51**, which is arranged in parallel and integrally molded with the resin molds **52** so that the signal wiring **50** is raised perpendicularly generally perpendicularly with respect to the connector board **68**.

[0074] Here, at this time, the power source terminal **621** of the power connector **62**, the signal terminals **631** of the sensor connector **63** and the signal terminals **641** of the signal connector **64** may be inserted into through holes of the connector board **68** from the same direction as the signal wiring **50**.

[0075] Subsequently, the terminals **51** of the signal wiring **50**, the leads of the choke coil **13**, and the leads of the first capacitor **12** are soldered to the connector board **68** from one direction. That is, they are soldered from a direction opposite to a direction, in which the terminals **51** of the signal wiring **50** are inserted.

[0076] In this way, the signal wiring **50**, the choke coil **13**, and the first capacitor **12** are mounted on the connector board **68** by one step. Here, the signal wiring **50** is raised perpendicularly on a side opposite to a face of the connector board **68**, to which these components are soldered, and hence does not interfere with a soldering operation.

[0077] Next, as shown in FIG. **10**, in the bending step, the terminals **51** of the signal wiring **50** are bent about 90 degrees in a direction to be parallel to the connector board **68** between a first predetermined resin mold **52** and a second predetermined resin mold **52**, which is adjacent to the first predetermined resin mold **52**.

[0078] Next, as shown in FIG. **11**, the terminals **51** of the signal wiring **50** are further bent about 90 degrees in a direction perpendicular to the connector board **68** between the second predetermined resin mold **52** and a third predetermined resin mold **52**, which is adjacent to the second predetermined resin mold **52**.

[0079] Finally, as shown in FIG. **7**, in the second mounting step, the other ends of the terminals **51** of the signal wiring **50** are inserted in the through holes of the control circuit board **43** and then are mounted on the control circuit board **43** by soldering. In this way, the signal wiring **50** electrically connects the control circuit **30** of the control circuit board **43** to the connector board **68**.

[0080] The present embodiment provides the following functions and advantages.

[0081] (1) The electronic control unit **3** of the motor drive apparatus **1** is provided with the electric connector **60**, which is passed through the hole **72** of the cover **70** from the component carrier **61** and extended to the side opposite to the output part **10** in the axial direction of the motor shaft **83**. In this way, even if a space, in which the motor drive apparatus **1** is set, is limited in the radial direction of the motor shaft **83**, the electric connector **60** of the motor drive apparatus **1** can be easily connected to the external connector of the vehicle in the axial direction of the motor **80**. Hence, the mounting operation of the motor drive apparatus **1** in the vehicle can be enhanced.

[0082] (2) The sealing member **73** made of the liquid gasket such as FIPG is disposed between the component carrier **61** and the cover **70** in such a way as to surround the electric

connector **60**. This can prevent water or a foreign matter from coming into the case from a clearance between the component carrier **61** and the cover **70**. Hence, the motor drive apparatus **1** can be easily fixed in an engine compartment of the vehicle.

[0083] (3) In the case where the power modules **40** and **41**, which include the switching elements **16** to **21**, and the electric connector **60** are projected to an imaginary plane perpendicular to the motor shaft **83**, a part or all of the electric connector **60** is positioned between the power modules **40** and **41**. That is, the electric connector **60** is positioned partly or fully between the power modules **40** and **41**. This can increase a region, in which the sealing member **73** is applied to the component carrier **61** around the electric connector **60**. Hence, the motor drive apparatus **1** can have high waterproof performance and dust resistance.

[0084] (4) The connector board **68** is electrically connected to the signal terminals **631**, **641** of the electric connector **60** and to the signal wiring **50**. By using the connector board **68**, the wiring for connecting the signal terminals **631** and **641** to the signal wiring **50** can be laid in the connector board **68**. Hence, the manufacturing cost of the motor drive apparatus **1** can be reduced and the size of the motor drive apparatus **1** can be reduced.

[0085] (5) When viewed in the direction of the motor shaft **83**, the signal wiring **50** is positioned in a direction perpendicular to a direction, in which one power module **40** is opposed to the other power module **41**. This can increase the distance between the signal wiring **50** and the power modules **40** and **41** and hence can reduce the influence that the electromagnetic wave generated by the large current passing through the power modules **40** and **41** produces on the signal wiring **50**.

[0086] (6) The signal wiring **50** has one end inserted into the through hole of the connector board **68** from the connector **60** side and is mounted on the connector board **68** in a state, in which the signal wiring **50** is raised perpendicularly with respect to the connector board **68**. Thereafter, the signal wiring **50** is bent to the control circuit board **43** side and hence is extended parallel to the motor shaft **83** and has the other end mounted on the control circuit board **43**. In this way, the signal terminals **631**, **641** of the electric connector **60** and the signal wiring **50** can be mounted on the connector board **68** from the same direction. For this reason, the signal terminals **631**, **641** of the electric connector **60** and the signal wiring **50** can be soldered to the connector board **68** by one step. Further, the signal wiring **50** is raised perpendicularly from the connector board **68** at a side opposite to a face, to which those components are soldered, and hence does not interfere with the soldering operation.

[0087] (7) The signal wiring **50** has the plurality of terminals **51** and the resin molds **52** for integrally molding the plurality of terminals **51** except for portions in which the plurality of terminals **51** are bent. In this way, the plurality of terminals **51** can be fixed to the connector board **68** or the control circuit board **43** at one time. Further, the plurality of terminals **51** can be bent at a time after the signal wiring **50** is mounted on the connector board **68**. Hence, the workability of fixing the signal wiring **50** can be improved.

[0088] (8) The plurality of terminals **51** have cutout portions **53**, in which bent portions have less thickness than other straight portions. In this way, the plurality of terminals **51** can be easily bent at a predetermined position.

Second Embodiment

[0089] A motor drive apparatus according to a second embodiment is shown in FIG. **12** and FIG. **13**. In the second embodiment, the substantially same constructions as in the first embodiment are denoted by the same reference signs and their descriptions will be omitted.

[0090] In the second embodiment, a signal wiring **500** is formed in a flexible flat wire set. In FIG. **13** is shown a flexible flat wire set before being fixed to the electronic control unit **3**. The flexible flat wire set is made by covering a plurality of plate-shaped conducting bodies **510** with an insulating body **520** such as paper. As shown in FIG. **12**, the signal wiring **500** has one end mounted on the connector board **68** from a connector side and bent to a control circuit board side and has the other end mounted on the control circuit board **43**. The signal wiring **500** electrically connects the control circuit **30** of the control circuit board **43** to the connector board **68**.

[0091] Further, a power wiring **560** for connecting the connection terminal **55** mounted on the connector board **68** to the power circuit board **42** is also formed in a flexible flat wire set.

[0092] The flexible flat wire sets are used for the signal wiring **500** and the power wiring **560** and hence the signal wiring **500** can be easily arranged. Hence, the workability of fixing the signal wiring **500** and the power wiring **560** can be improved and hence man-hours required to assemble the electronic control unit **3** can be reduced.

Other Embodiments

[0093] In the embodiments described above, the motor drive apparatus is exemplified as being fixed in parallel to the shaft of the rack of the vehicle. However, the motor drive apparatus may be fixed to a column shaft of the vehicle. The motor drive apparatus is not limited to the embodiments described above, but may be implemented differently.

What is claimed is:

1. A motor drive apparatus comprising:

a motor having a motor shaft;

a motor case for housing the motor;

an output part protruded from the motor case in one direction of the motor shaft for outputting torque of the motor;

a heat sink disposed on a side axially opposite to the output part of the motor case;

a connector disposed on a side axially opposite to the output part relative to the heat sink and provided with a power source terminal, which supplies a current for driving the motor, and signal terminals, which supplies signals for controlling drive of the motor;

a component carrier formed integrally with the connector and fixed to the heat sink;

a plurality of switching elements fixed to the heat sink and for converting the current supplied to the power source terminal of the connector into a current for driving the motor;

a power circuit board disposed on the heat sink at a side opposite to the output part and provided with a wiring, through which the current for driving the motor is passed from the power source terminal of the connector via the switching elements;

a control circuit board disposed on the heat sink at an output part side and provided with a control circuit for controlling operations of the switching elements based on signals supplied to the signal terminals of the connector; and

a cover housing the heat sink, the component carrier, the switching elements, the control circuit board and the power circuit board, and having a hole through which the connector is passed at a side opposite to the output part,

wherein the connector is extended from the component carrier to pass through the hole of the cover to an outside of the cover at a side opposite to the output part.

2. The motor drive apparatus according to claim **1**, further comprising:

a sealing member that surrounds the connector and is interposed between the component carrier and the cover.

3. The motor drive apparatus according to claim **2**, wherein:

the heat sink has a plurality of side wall parts arranged symmetrically with respect to an axis of the motor shaft of the motor;

the plurality of switching elements are fixed to the plurality of side wall parts; and

the connector is positioned partially or entirely between a part of the switching elements and other part of the switching elements, in a case where the connector and the switching elements are projected to an imaginary plane perpendicular to the motor shaft of the motor.

4. The motor drive apparatus according to claim **1**, further comprising:

a connector board disposed on the component carrier at a control circuit board side and electrically connected to the signal terminals of the connector; and

a signal wiring for electrically connecting the control circuit of the control circuit board to the connector board.

5. The motor drive apparatus according to claim **4**, wherein:

the signal wiring has one end mounted on the connector board from a connector side and has other end mounted on the control circuit board, the signal wiring being bent to extend toward the control circuit board side in parallel to the axis of the motor shaft between the one end and the other end.

6. The motor drive apparatus according to claim **4**, wherein:

the signal wiring is positioned in a direction perpendicular to a direction, in which a part of the switching elements and other part of the switching elements face, when viewed in a direction of the motor shaft.

7. The motor drive apparatus according to claim **4**, wherein:

the signal wiring has a plurality of terminals and a resin mold for integrally molding the plurality of terminals except for a bent portion, at which the plurality of terminals are bent.

8. The motor drive apparatus according to claim **7**, wherein:

the plurality of terminals has a cutout portion, in which the bent portion is small in thickness.

9. The motor drive apparatus according to claim **4**, wherein:

the signal wiring is formed in a flexible flat wire set.

10. The motor drive apparatus according to claim **1**, further comprising:

a connection terminal electrically connected to the power source terminal of the connector;

a power wiring extended from the power circuit board; and

a connection part for connecting the connection terminal to the power wiring,

wherein the connection part is supported by the component carrier.

11. The motor drive apparatus according to claim **2**, further comprising:

a connector board disposed on the component carrier at a control circuit board side and electrically connected to the signal terminals of the connector; and

a signal wiring for electrically connecting the control circuit of the control circuit board to the connector board.

12. The motor drive apparatus according to claim **3**, further comprising:

a connector board disposed on the component carrier at a control circuit board side and electrically connected to the signal terminals of the connector; and

a signal wiring for electrically connecting the control circuit of the control circuit board to the connector board.

13. The motor drive apparatus according to claim **2**, further comprising:

a connection terminal electrically connected to the power source terminal of the connector;

a power wiring extended from the power circuit board; and

a connection part for connecting the connection terminal to the power wiring,

wherein the connection part is supported by the component carrier.

14. The motor drive apparatus according to claim **3**, further comprising:

a connection terminal electrically connected to the power source terminal of the connector;

a power wiring extended from the power circuit board; and

a connection part for connecting the connection terminal to the power wiring,

wherein the connection part is supported by the component carrier.

15. A method for manufacturing the motor drive apparatus according to claim **4**, the method comprising:

a first mounting step of inserting one end of the signal wiring into the connector board from a connector side and soldering the signal wiring to the connector board in a state where the signal wiring is raised perpendicularly with respect to the connector board;

a bending step of bending the signal wiring toward the control circuit board; and

a second mounting step of mounting other end of the signal wiring on the control circuit board.

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