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(54) Title: ELECTRIC DRIVE UNIT LAYOUT

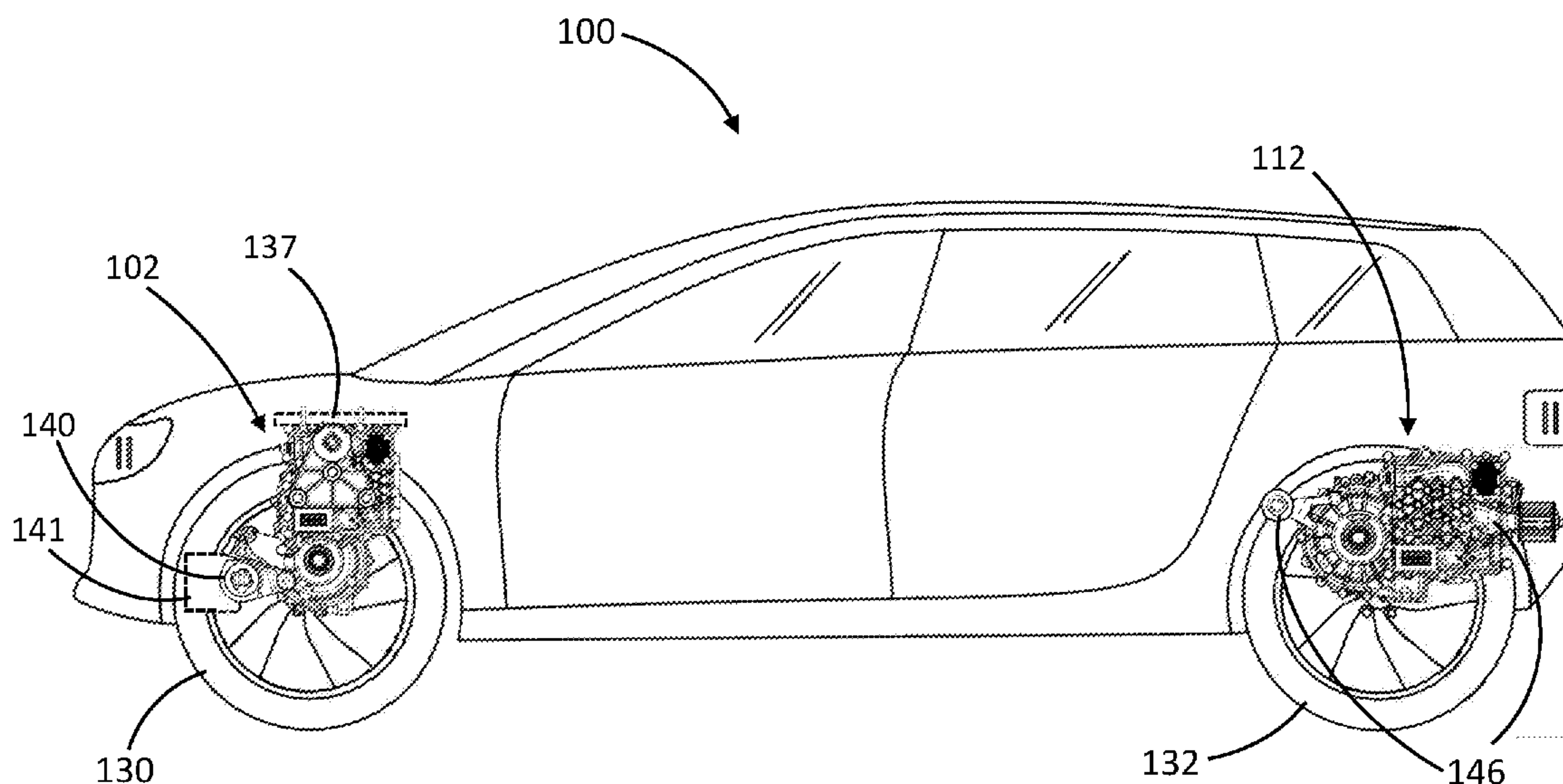


Figure 1

(57) **Abstract:** A vehicle (100) comprising first (102) and second (112) electric drive units having first and second elongate axes (110,120). Each electric drive unit comprises a gearbox (104,114), an electric motor (106,116) mounted to the gearbox (104,114) and configured to provide drive to the gearbox (104,114), and an inverter (108,118) mounted to the gearbox (104,114) and configured to provide drive current to the electric motor (106,116). The first electric drive unit (102) is mounted with the first axis (110) at a first pitch angle relative to the vehicle (100), the second electric drive unit (112) is mounted with the second axis (120) at a second pitch angle relative to the vehicle (100). The first and second pitch angles are different to each other. The first (108) and second (118) inverters are mounted with the same orientation relative to the vehicle (100).

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ELECTRIC DRIVE UNIT LAYOUT

Field of the Invention

- 5 The present invention relates to an electric vehicle having at least first and second electric drive units (EDUs), each having an inverter.

Background of the Invention

- 10 Electric and hybrid electric vehicles are becoming increasingly common. One such vehicle may comprise front and rear electric drive units (EDUs), each driving a corresponding pair of road wheels.

An EDU may include a gearbox, an inverter, and an electric motor.

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The use of at least two EDUs may complicate manufacture and assembly of the vehicle relative to a vehicle that employs only a single EDU. This may be exacerbated if there is a desire to mount the EDUs differently at the front and rear of the vehicle, for example due to packaging constraints.

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It would be desirable to reduce manufacturing and/or assembly complexity in an electric or hybrid electric vehicle having at least first and second EDUs.

Summary of the Invention

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The present invention provides a vehicle comprising:

a first electric drive unit having a first elongate axis and comprising:

a first gearbox, the first elongate axis being orthogonal to both input and output rotational axes of the first gearbox;

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a first electric motor mounted to the first gearbox and configured to provide drive to the first gearbox; and

a first inverter mounted to the first gearbox and configured to provide drive current to the first electric motor; and

a second electric drive unit having a second elongate axis and comprising:

a second gearbox, the second elongate axis being orthogonal to both input and output rotational axes of the second gearbox;

a second electric motor mounted to the second gearbox and configured to provide drive to the second gearbox; and

a second inverter mounted to the second gearbox and configured to provide drive current to the second electric motor;

wherein:

the first electric drive unit is mounted with the first elongate axis at a first pitch angle relative to the vehicle;

the second electric drive unit is mounted with the second elongate axis at a second pitch angle relative to the vehicle, the first and second pitch angles being different to each other; and

the first and second inverters are mounted with the same orientation relative to the vehicle.

The use of the same orientation for the first and second inverters, despite the respective electric drive units having different pitch angles relative to the vehicle, may simplify the process of assembling the inverters to the gearboxes, and installation of the electric drive units into the vehicle.

The pitch angle is measured relative to the vehicle body, for example relative to a lower surface of the vehicle body that is substantially parallel to a surface upon which the vehicle is disposed in use.

The respective orientations of the inverters may be defined based on positions of electrical connections on the respective first and second inverters, and/or coolant connections on the respective first and second inverters.

The respective housings of the first inverter and the second inverter may be the same as each other. This may make the process of mounting the inverters to their respective gearboxes more efficient, because the same tools, fasteners, and assembly methods may be used even though the gearboxes themselves are mounted at a different pitch, and optionally may structurally be different to each other. The use of the same housing may simplify the supply chain, as only a single housing need be designed, manufactured and stocked.

The first inverter and the second inverter may be the same as each other, which may further simplify the supply chain.

The first electric drive unit may be configured to drive a set of front wheels of the vehicle.

The second electric drive unit may be configured to drive a set of rear wheels of the vehicle.

Where the first electric drive unit is configured to drive a set of front wheels of the vehicle and the second electric drive unit is configured to drive a set of rear wheels of the vehicle, the orientation of the inverters may be selected to improve or optimise packaging efficiency.

The pitch angle of one of the first electric drive unit and the second electric drive unit may be less than 45° , and the pitch angle of the other of the first electric drive unit and the second electric drive unit may greater than 45° . These pitch angle ranges may offer improved or optimised packaging efficiency.

The first electric drive unit may be positioned to drive a set of front wheels of the vehicle, and the pitch angle of the first electric drive unit may be substantially vertical. The second electric drive unit may be positioned to drive a set of rear wheels of the vehicle, and the pitch angle of the second electric drive unit may be substantially horizontal. This combination of pitch angles may offer improved or optimised packaging efficiency, by

enabling the vehicle to have a longitudinally compact nose and a relatively tall load space to the rear.

5 The first and second electric motors may be mounted to their respective gearboxes at different orientations relative to the vehicle, wherein the respective orientations of the first and second electric motors are defined based on positions of electrical connections on the respective first and second electric motors, and/or coolant connections on the respective first and second electric motors. Different orientations of the electric motors may allow improved or optimised positioning of the electrical connections and/or coolant
10 connections relative to the respective installation positions of the first and second electric drive units.

The first and second electric motors may be the same as each other. This makes the process of mounting the electric motors to their respective gearboxes more efficient,
15 because the same tools, fasteners, and assembly methods may be used even though the gearboxes themselves are mounted at a different pitch. The use of the same electric motor may simplify the supply chain, as only a single electric motor need be designed, manufactured and stocked.

20 Each of the inverters may be mounted to its gearbox on a side opposite that to which the corresponding electric motor is mounted. This arrangement may assist in placing the gearbox relatively close to a centreline of the vehicle, which offers improved or optimised packaging efficiency.

25 The first electric drive unit may comprise a pair of laterally-positioned, weight-bearing mounts connected to a body of the vehicle at a respective pair of mounting points at or adjacent respective front shock towers. This may offer a compact mounting arrangement.

The first electric drive unit may comprise at least one torque-reaction mount connected
30 to a body of the vehicle at a position lower than the weight-bearing mounts. This may

enable effective transfer of torque between the first electric drive unit and the vehicle while optionally allowing for a relatively vertically positioned gearbox.

5 The second electric drive unit may comprise a plurality of combined weight-bearing and torque-reaction mounts that connect the second electric drive unit to a body of the vehicle at corresponding mounting points thereof. This may enable effective mounting and torque-transfer while optionally allowing for a relatively horizontally positioned gearbox.

10 The first gearbox may be different to the second gearbox, for example having a different housing or internal structure. This may allow each gearbox to be optimised for its intended mounting orientation.

15 The first and second electric drive units may include mounting points to which respective mounts may be attached. This may allow for a compact electric drive unit and mount assembly. In at least one embodiment, the same mounting points are present on the first and second electric drive units, but the first and second electric drive units have different mounts attached to their respective mounting points.

Brief Description of the Drawings

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In order that the present invention may be more readily understood, embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

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Figure 1 is a partially see-through side view of a vehicle comprising a first, front-mounted electric drive unit (EDU) and a second, rear-mounted EDU;

Figure 2 is a partially see-through front view of the vehicle of Figure 1, showing the first EDU of Figure 1;

Figure 3 is a partially see-through rear view of the vehicle of Figure 1, showing the second EDU of Figure 1;

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Figure 4 is a side view of the first EDU;

Figure 5 is a perspective view of the first EDU, with mounts omitted for clarity;

Figure 6 is a side view of the second EDU;

Figure 7 is a perspective view of the second EDU, with mounts omitted for clarity;

Figure 8 is an underside view of the second EDU;

Figure 9 is an underside view of the second EDU, mounted to a subframe of the vehicle of Figure 1.

Detailed Description of the Invention

Referring to the drawings, a vehicle 100 comprises a first electric drive unit (EDU) 102. The first EDU 102 includes a first gearbox 104. A first electric motor 106 is mounted to the first gearbox 104 and configured to provide drive to an input shaft (not shown) of the first gearbox 104. A first inverter in the form of a first inverter 108 is mounted to the first gearbox 104 and configured to provide drive current to the first electric motor 106.

In the embodiment shown, the first electric motor 106 is mounted to a first lateral side of the first gearbox 104, and the first inverter 108 is mounted to a second lateral side of the first gearbox 104 opposite the first lateral side. The first EDU 102 is generally T-shaped, with the first gearbox 104 forming an upright of the 'T', and the first inverter 108, first electric motor 106 and upper end of the first gearbox 104 forming a crossbar of the 'T'.

The first EDU 102 has an elongate axis 110 extending generally through the first gearbox 104. As best shown in Figures, 2, 4 and 5, the elongate axis 110 is defined in this embodiment as an axis orthogonal to both the input and output rotational axes of the first gearbox 104. The elongate axis 110 extends generally through the center line through the first gearbox 104.

The vehicle 100 comprises a second EDU 112. The second EDU 112 includes a second gearbox 114. A second electric motor 116 is mounted to the second gearbox 114 and configured to provide drive to an input shaft (not shown) of the second gearbox 114. A second inverter in the form of a second inverter 118 is mounted to the second gearbox 114 and configured to provide drive current to the second electric motor 116.

In the embodiment shown, the second electric motor 116 is mounted to a first lateral side of the second gearbox 114, and the second inverter 118 is mounted to a second lateral side of the second gearbox 114 opposite the first lateral side. The second EDU 112 is generally T-shaped, with the second gearbox 114 forming an upright of the 'T', and the
5 second inverter 118, second electric motor 116 and upper end of the second gearbox 114 forming a crossbar of the 'T'.

The second EDU 112 has an elongate axis 120 extending generally through the second gearbox 114. As best shown in Figures 6 and 7, the elongate axis 120 is defined in this
10 embodiment as an axis orthogonal to both the input and output rotational axes of the second gearbox 114. The elongate axis 120 extends generally through the center line of the second gearbox 114.

The first EDU 102 is mounted with its axis 110 at a first pitch angle, and the second EDU
15 112 is mounted with its axis 120 at a second pitch angle. The first pitch angle and the second pitch angles are different to each other.

The first pitch angle may be greater than 45° . In the illustrated embodiment, the first pitch angle is approximately vertical. The word "vertical" in this context is used with its
20 ordinary meaning, and is not necessarily limited to exactly 90° .

The second pitch angle may be less than 45° . In the illustrated embodiment, the second pitch angle is approximately horizontal. The word "horizontal" in this context is used with its ordinary meaning, and is not necessarily limited to exactly 0° .

As best shown by comparing Figures 4 and 6, the first inverter 108 and the second inverter 118 are mounted to their respective gearboxes such that the inverters 108,118 have the same orientation relative to the vehicle 100. In this case, the orientation of the first inverter 108 and the second inverter 118 is such that a straight upper edge of the inverters is
25
30 approximately horizontal.

The respective orientations of the first inverter 108 and the second inverter 118 may be defined based on positions of coolant connections on the respective first and second inverters. Referring to Figures 4 and 6, for example, a first coolant inlet 122 is positioned in the same place on the first inverter 108 as a second coolant inlet 124 on the second inverter 118. Similarly, a first coolant outlet 126 is positioned in the same place on the first inverter 108 as a second coolant outlet 128 on the second inverter 118. It may be desirable in at least some implementations that the coolant inlets and outlets be horizontal, because this helps avoid unnecessary turns in the cooling pipework.

Alternatively, or in addition, the respective orientations of the first inverter 108 and the second inverter 118 may be defined based on positions of electrical connections on the respective first and second inverters.

In the illustrated embodiment, the first inverter 108 and the second inverter 118 are the same as each other. In this context, “the same” means that they share the same housing and internal electronics components. In practice, this may mean that the first inverter 108 and second inverter 118 are effectively the same part.

In alternative embodiments, the respective housings of the first inverter 108 and the second inverter 118 can be the same as each other, while the internal components are different. This may be the case when, for example, the first EDU 102 has different torque requirements to the second EDU 112, and so fewer and/or lower-rated electronic switching components may be used for the inverter of the lower-torque EDU.

In yet other embodiments, the overall structure and/or layout of the inverters can be generally similar, but the details of the inverter housings are different to account for differences in requirements for mounting to the first and second EDUs.

The illustrated example shows the first EDU 102 driving a set of front wheels 130 of the vehicle 100, and the second EDU 112 driving a set of rear wheels 132 of the vehicle 100.

In this embodiment, the respective orientations of the inverters improve packaging efficiency.

In the illustrated embodiment, the first electric motor 106 is mounted to the first gearbox 104 at a different orientation to that at which the second electric motor 116 is mounted to the second gearbox 114. The respective orientations of the first and second electric motors may be defined based on positions of electrical connections on the respective first and second electric motors, and/or coolant connections on the respective first and second electric motors. As can be seen, in the present embodiment the first electric motor 106 is rotated relative to the second electric motor 116, with the rotation being performed about the axis of the output shaft of the respective electric motor 106, 116.

In the illustrated embodiment, the first electric motor 106 is the same as the second electric motor. This makes the process of mounting the electric motors to their respective gearboxes more efficient, because the same tools, fasteners, and assembly methods may be used even though the gearboxes themselves are mounted at a different pitch.

In the illustrated embodiment, the first EDU 102 comprises a pair of laterally-positioned, weight-bearing mounts 134 connected to the vehicle 100 at mounting points 136 on a cross-member 137 that extends between front shock towers 138. The first EDU 102 also comprises a torque-reaction mount 140 connected to a subframe 141 (see Fig. 1) of the vehicle 100 at a position lower than the weight-bearing mounts 134. It will be appreciated that other combinations of weight-bearing and/or torque-reaction mounts may be employed, depending upon packaging requirements for example.

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The weight-bearing mount 134 on the inverter side of the first EDU 102 is bolted directly to the first inverter 108 by way of bolts 142 (see Figure 4) screwed into corresponding threaded bosses 144 (see Figure 5) on the first inverter 108. The weight-bearing mount 134 on the electric motor side of the first EDU 102 is bolted directly to the electric motor in a similar fashion.

30

The torque reaction mount 140 is bolted directly to the gearbox 104 by way of bolts 143 (see Figure 4) screwed into corresponding threaded bosses 145 (see Figure 5) on both lateral sides of the gearbox 104.

5 As best shown in Figures 6 and 8, in the illustrated embodiment, the second EDU 112 comprises a plurality of combined weight-bearing and torque-reaction mounts 146 that connect the second EDU 112 to the vehicle 100 at corresponding mounting points 148 on a rear subframe 150 of the vehicle 100. Details of the mounting points 148 and rear subframe 150 are not pertinent to the present invention, and so will not be described here
10 for the sake of brevity.

The mount 146 on the inverter side of the second EDU 112 is bolted directly to the second inverter 118 by way of bolts 152 (See Figure 6) screwed into corresponding threaded bosses 154 (see Figure 7) on the second inverter 118. The mount 146 on the electric motor
15 side of the second EDU 112 is bolted directly to the electric motor in a similar fashion. The remaining mount 146 is bolted directly to the second gearbox 114 at a forward end of the second EDU 112.

In the illustrated embodiments, the mounts are separate elements attached to the inverters,
20 electric motors and gearboxes. In other embodiments, one or more of the mounts may form part of the corresponding electric motor, inverter or gearbox, in which case a separate mount element is not required. Alternatively, one or more of the mounts may be attached to, or form part of, a part of the EDU other than the inverter and/or the electric motor. For example, all mounts on one or more of the EDUs may be attached to, or form
25 part of, the gearbox.

In the illustrated embodiment, the first gearbox 104 is different to the second gearbox 114. To account for the different orientations, internal features may be different between the gearboxes. For example, internal splash lubrication features are positioned to account
30 for each gearbox's specific orientation. The gearboxes may, however, have the same gearset, especially in embodiments where the first and second electric motors are the same

as each other. Where one electric motor has a higher peak torque than the other, the gearset of its gearbox may include stronger, more resilient components.

Although the illustrated vehicle 100 is a car, the invention may find application in other
5 types of vehicles, such as trucks and vans.

Although the invention has been described with reference to specific examples, it will be appreciated that the invention may be embodied in many other forms that fall within the scope of the appended claims.

CLAIMS

1. A vehicle comprising:

a first electric drive unit having a first elongate axis and comprising:

a first gearbox, the first elongate axis being orthogonal to both input and
5 output rotational axes of the first gearbox;

a first electric motor mounted to the first gearbox and configured to
provide drive to the first gearbox; and

a first inverter mounted to the first gearbox and configured to provide drive
current to the first electric motor; and

10 a second electric drive unit having a second elongate axis and comprising:

a second gearbox, the second elongate axis being orthogonal to both input
and output rotational axes of the second gearbox;

a second electric motor mounted to the second gearbox and configured to
provide drive to the second gearbox; and

15 a second inverter mounted to the second gearbox and configured to
provide drive current to the second electric motor;

wherein:

the first electric drive unit is mounted with the first elongate axis at a first pitch
angle relative to the vehicle, wherein the pitch angle is oriented relative to a surface of a
20 body of the vehicle that is substantially parallel to a flat surface upon which the vehicle
is disposed in use;

the second electric drive unit is mounted with the second elongate axis at a second
pitch angle relative to the vehicle, the first and second pitch angles being different to each
other; and

25 the first and second inverters are mounted with the same orientation relative to the
vehicle.

2. The vehicle of claim 1, wherein the respective orientations of the inverters are
defined based on positions of:

30 electrical connections on the respective first and second inverters; and/or
coolant connections on the respective first and second inverters.

3. The vehicle of claim 1 or 2, wherein housings of the first inverter and the second inverter are the same as each other.

5 4. The vehicle of claim 3, wherein the first inverter and the second inverter are the same as each other.

5. The vehicle of any preceding claim, wherein the first electric drive unit is configured to drive a set of front wheels of the vehicle.

10

6. The vehicle of any preceding claim, wherein the second electric drive unit is configured to drive a set of rear wheels of the vehicle.

7. The vehicle of any preceding claim, wherein the pitch angle of one of the first
15 electric drive unit and the second electric drive unit is less than 45° , and the pitch angle of the other of the first electric drive unit and the second electric drive unit is greater than 45° .

8. The vehicle of any one of claims 1 to 4, wherein:
20 the first electric drive unit is positioned to drive a set of front wheels of the vehicle, and the pitch angle of the first electric drive unit is substantially vertical; and
the second electric drive unit is positioned to drive a set of rear wheels of the vehicle, and the pitch angle of the second electric drive unit is substantially horizontal.

25 9. The vehicle of any preceding claim, wherein the first and second electric motors are mounted to their respective gearboxes at different orientations relative to the vehicle, wherein the respective orientations of the first and second electric motors are defined based on positions of:

electrical connections on the respective first and second electric motors; and/or
30 coolant connections on the respective first and second electric motors.

10. The vehicle of any preceding claim, wherein the first and second electric motors are the same as each other.

11. The vehicle of any preceding claim, wherein each of the inverters is mounted to
5 its gearbox on a side opposite that to which the corresponding electric motor is mounted.

12. The vehicle of any preceding claim, wherein the first electric drive unit comprises a pair of laterally-positioned, weight-bearing mounts connected to a body of the vehicle at a respective pair of mounting points at or adjacent respective front shock towers.

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13. The vehicle of any preceding claim, wherein the first electric drive unit comprises at least one torque-reaction mount connected to a body of the vehicle at a position lower than the weight-bearing mounts.

15 14. The vehicle of any preceding claim, wherein the second electric drive unit comprises a plurality of combined weight-bearing and torque-reaction mounts that connect the second electric drive unit to a body of the vehicle at corresponding mounting points thereof.

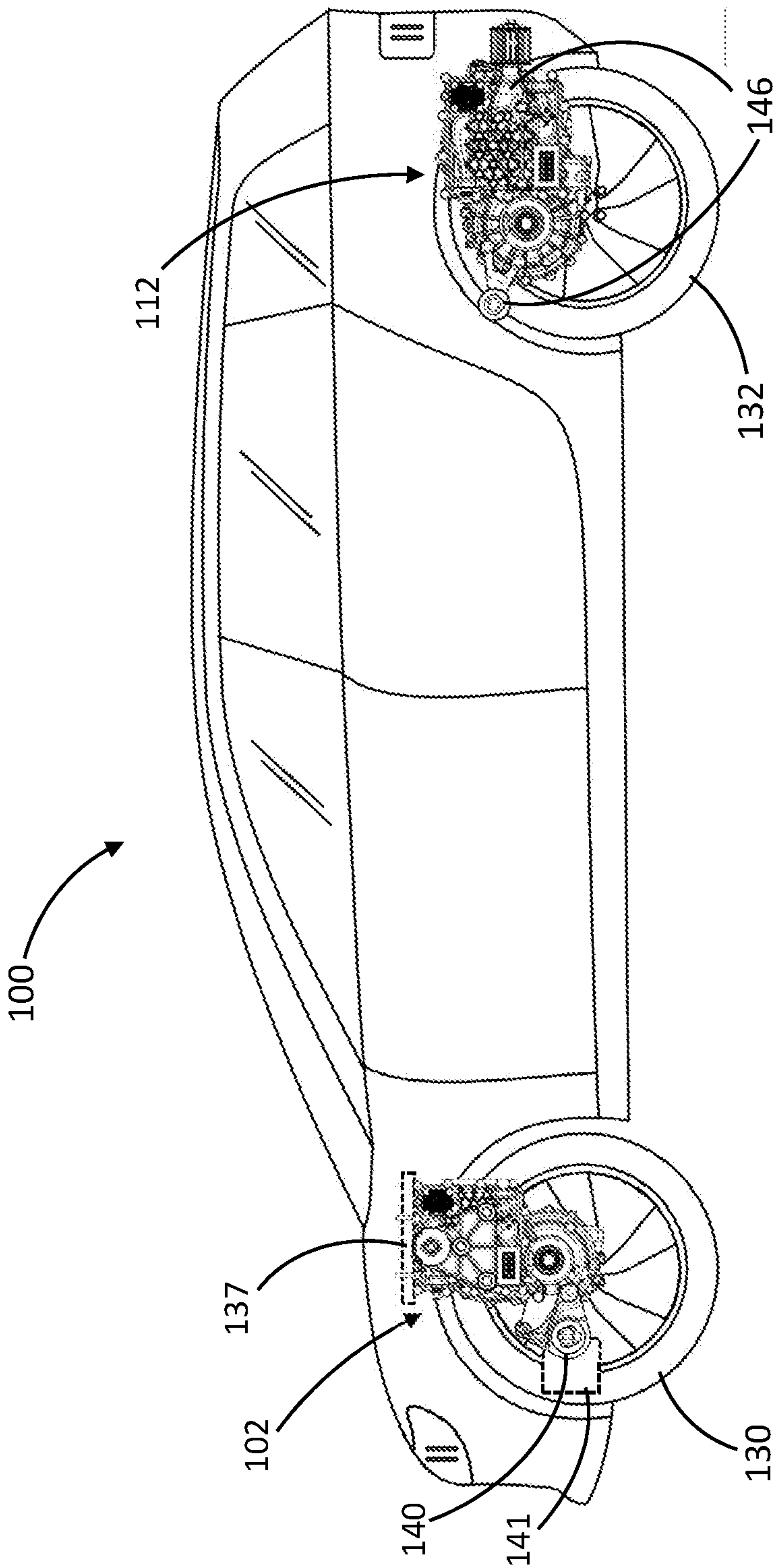


Figure 1

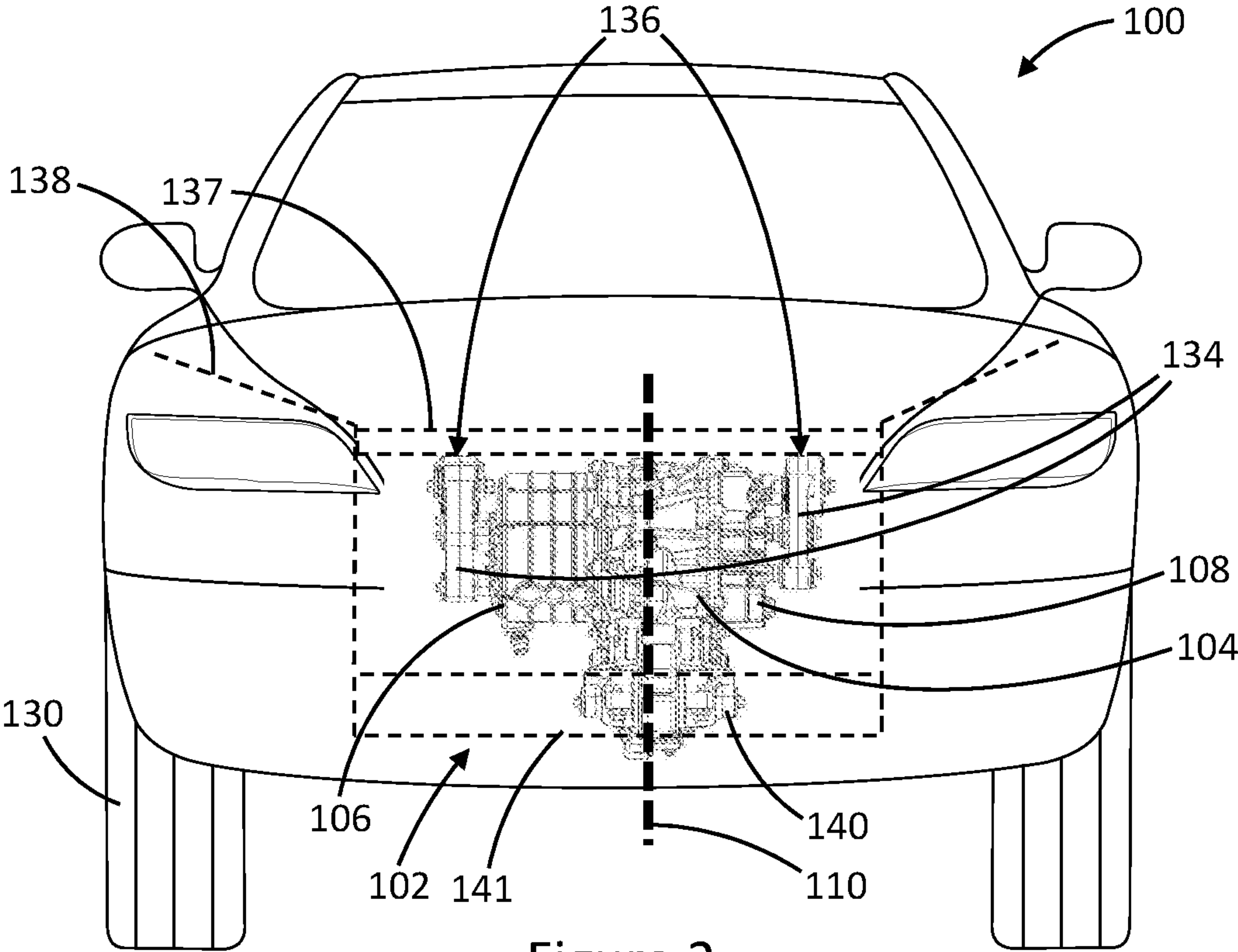


Figure 2

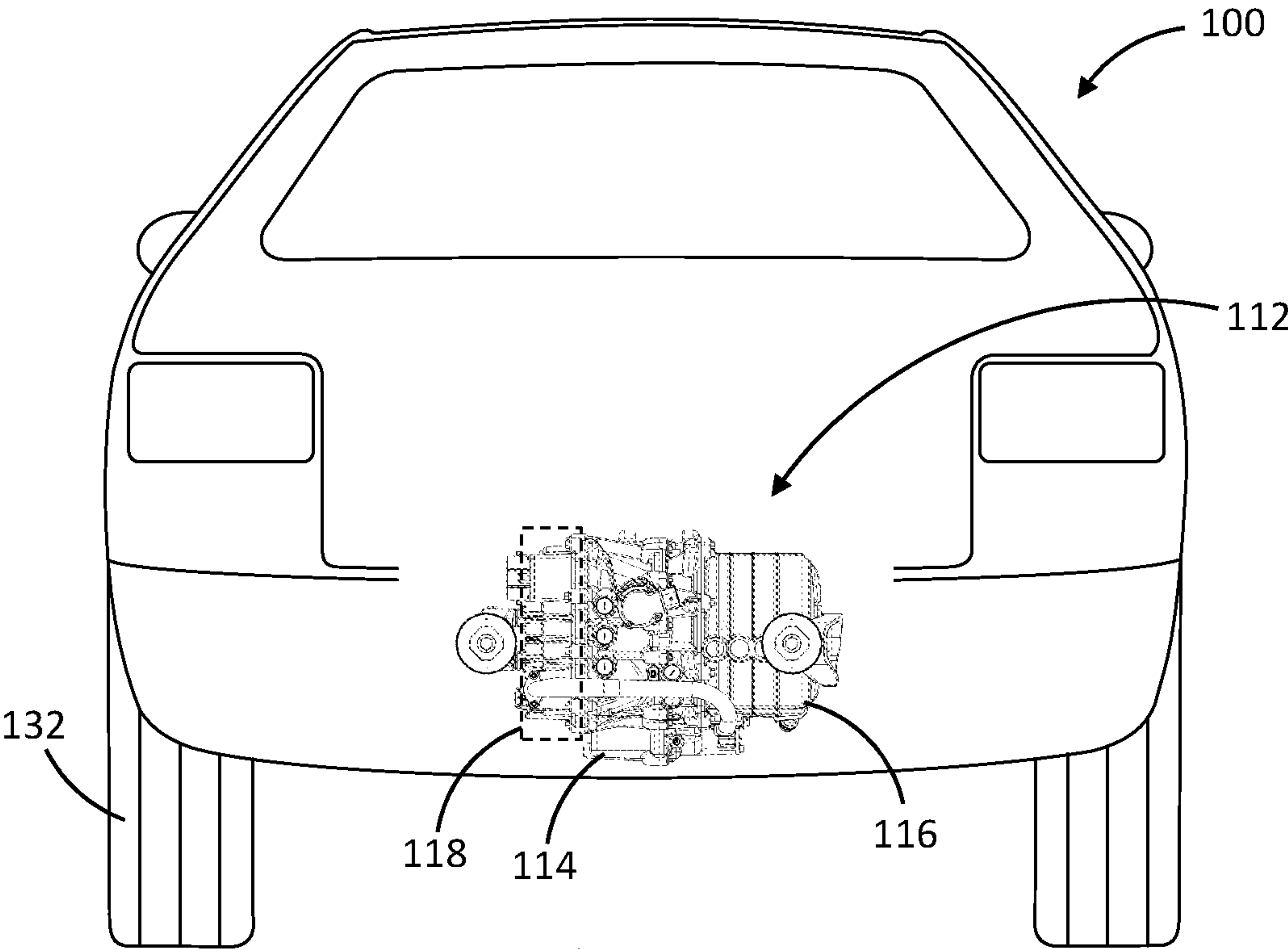


Figure 3

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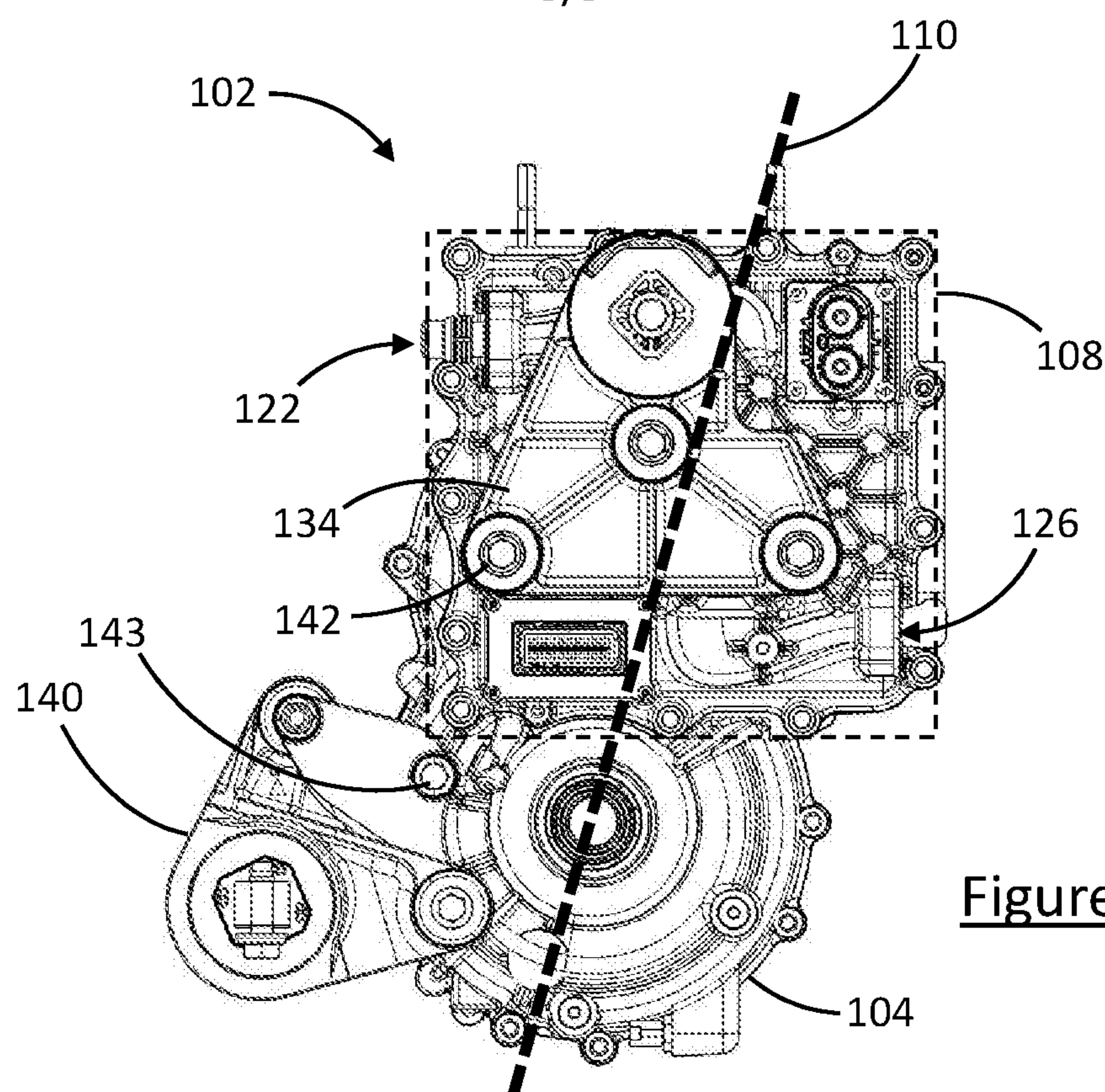


Figure 4

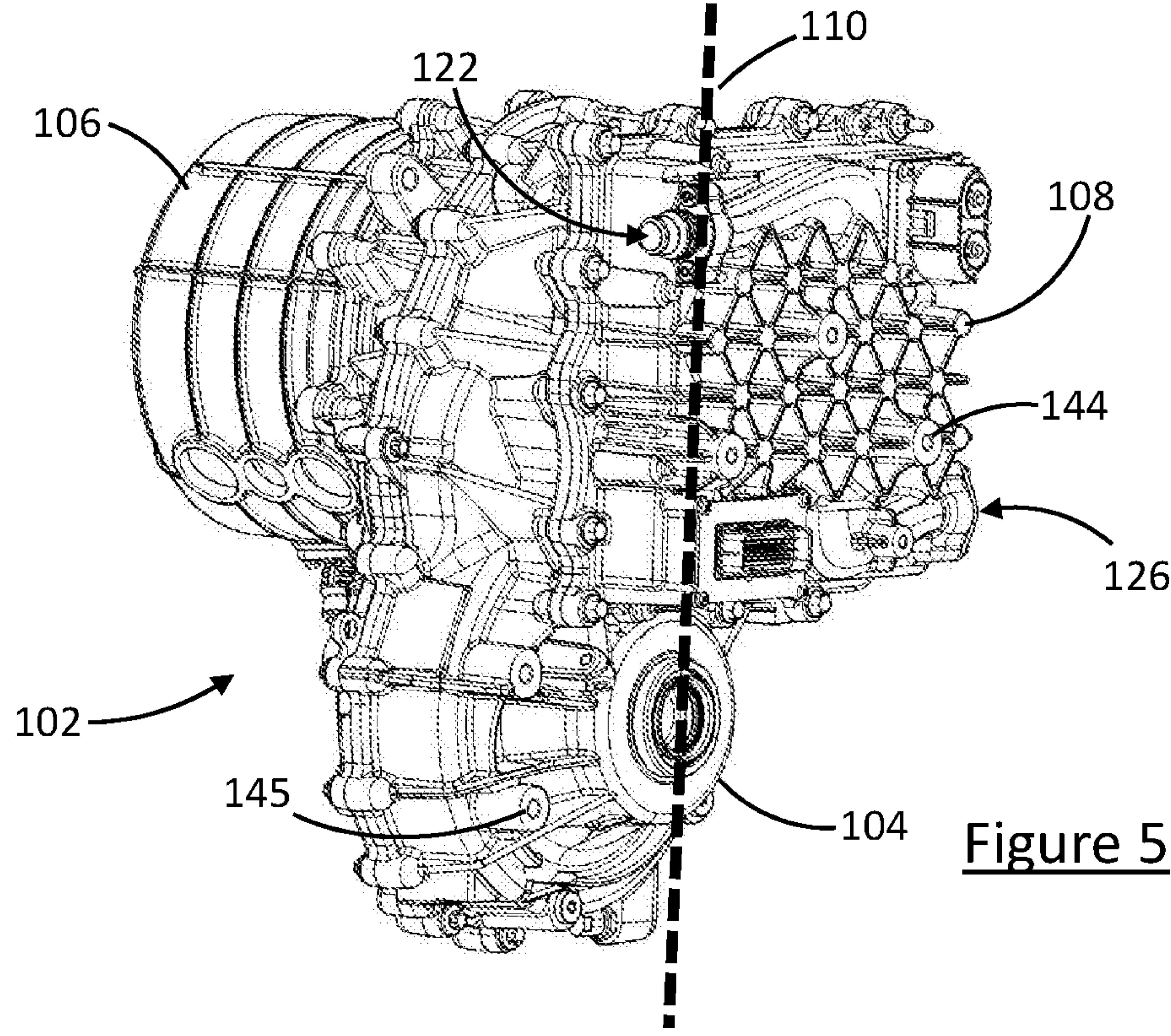


Figure 5

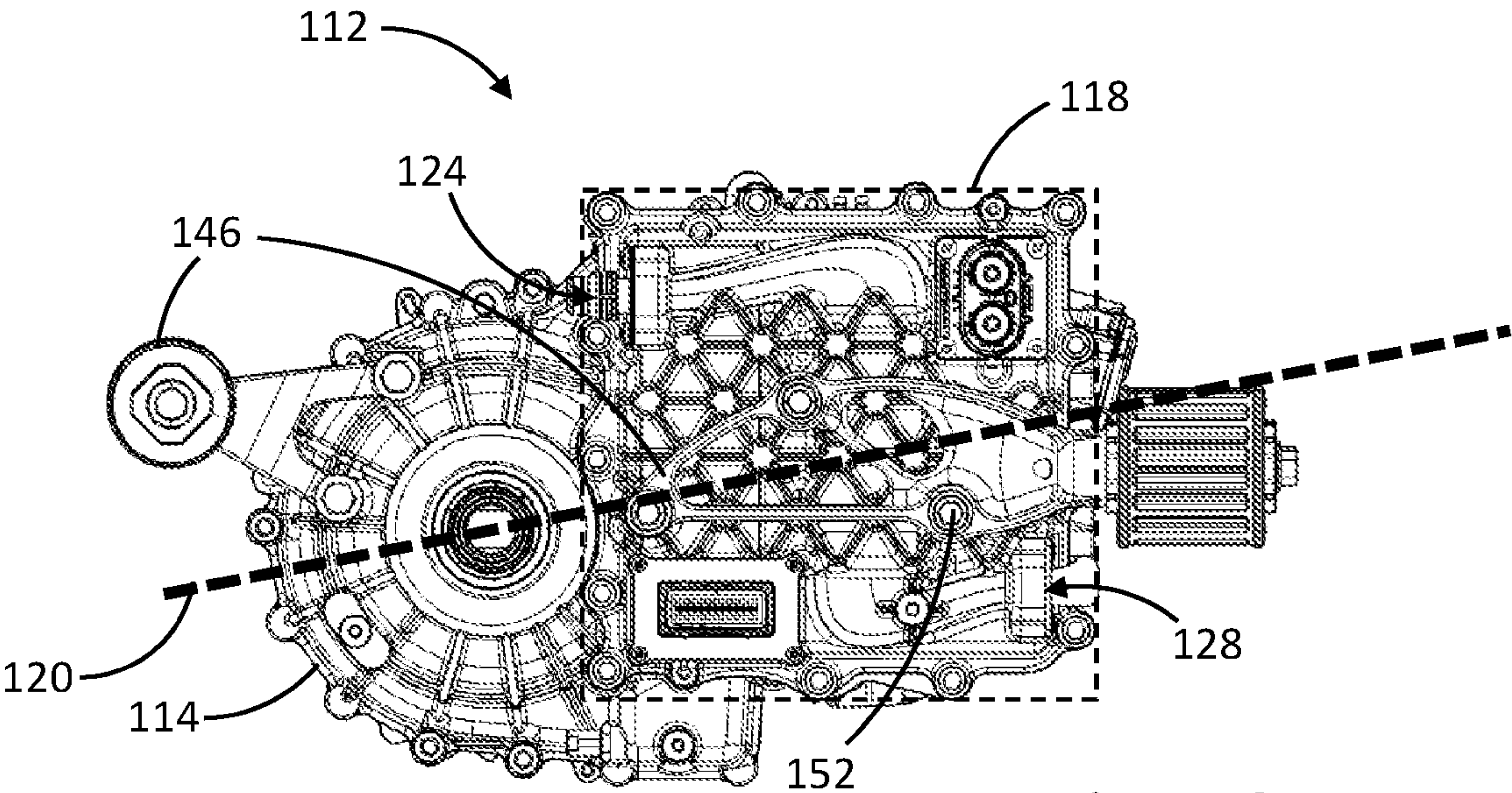


Figure 6

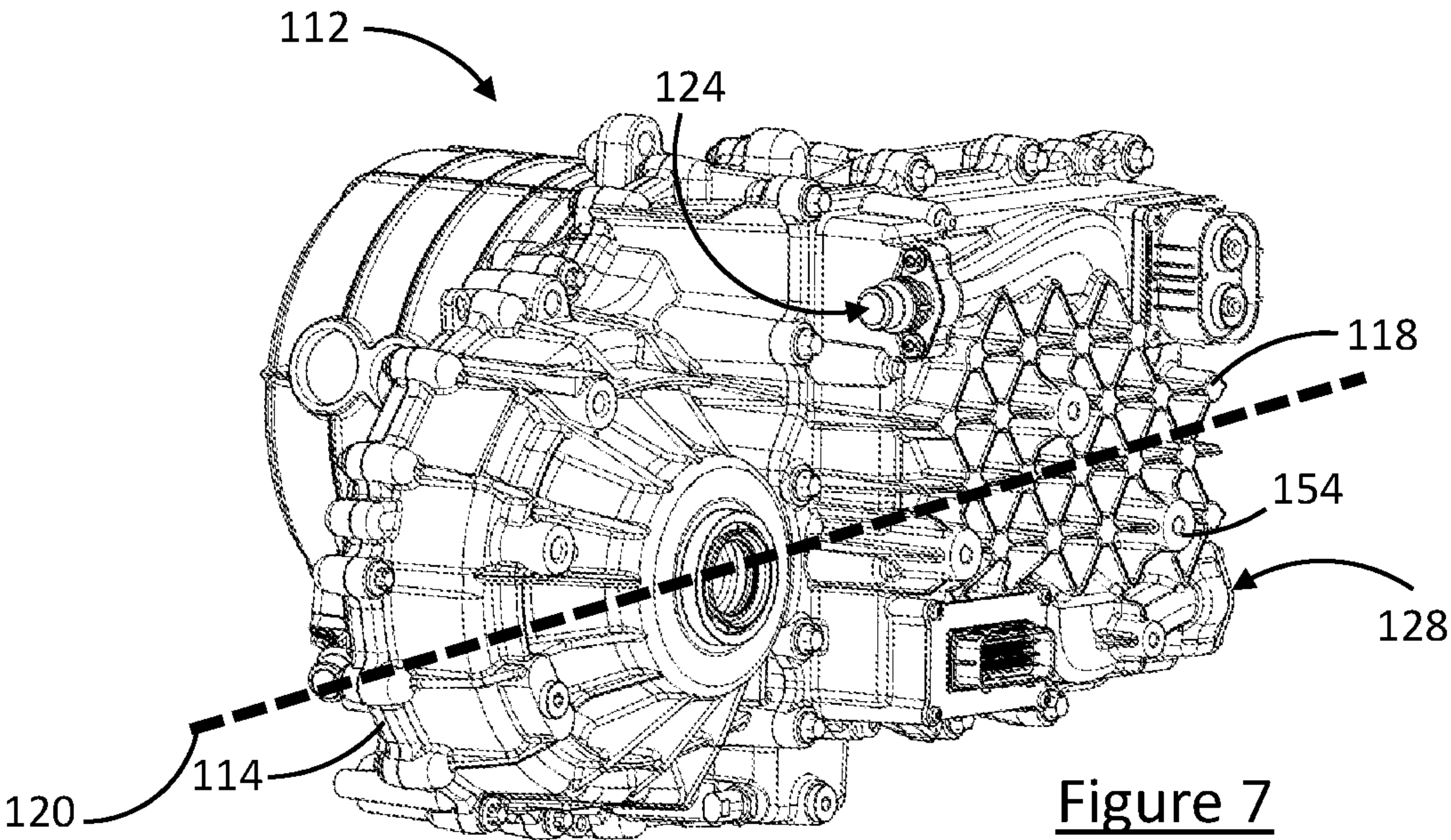


Figure 7

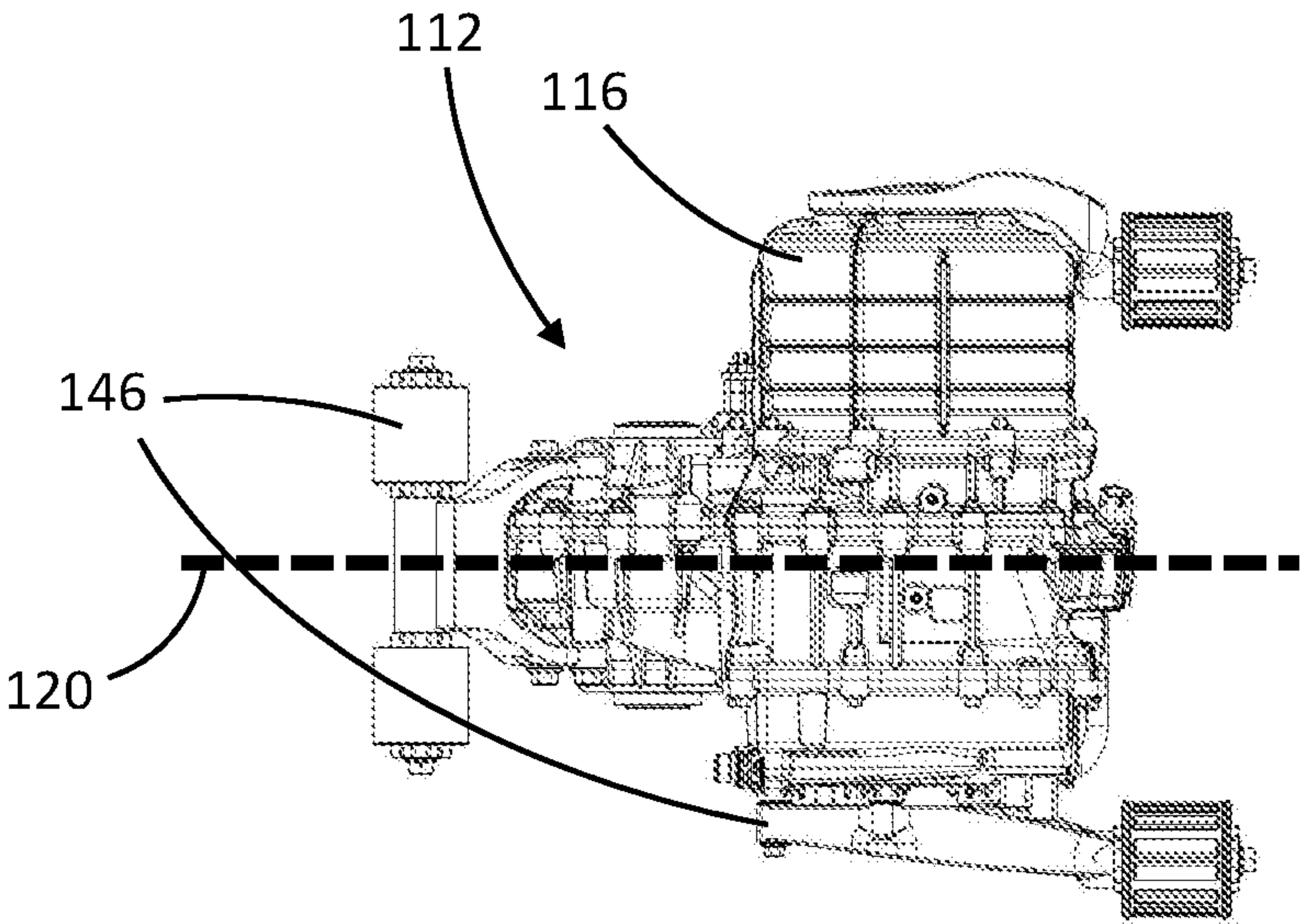


Figure 8

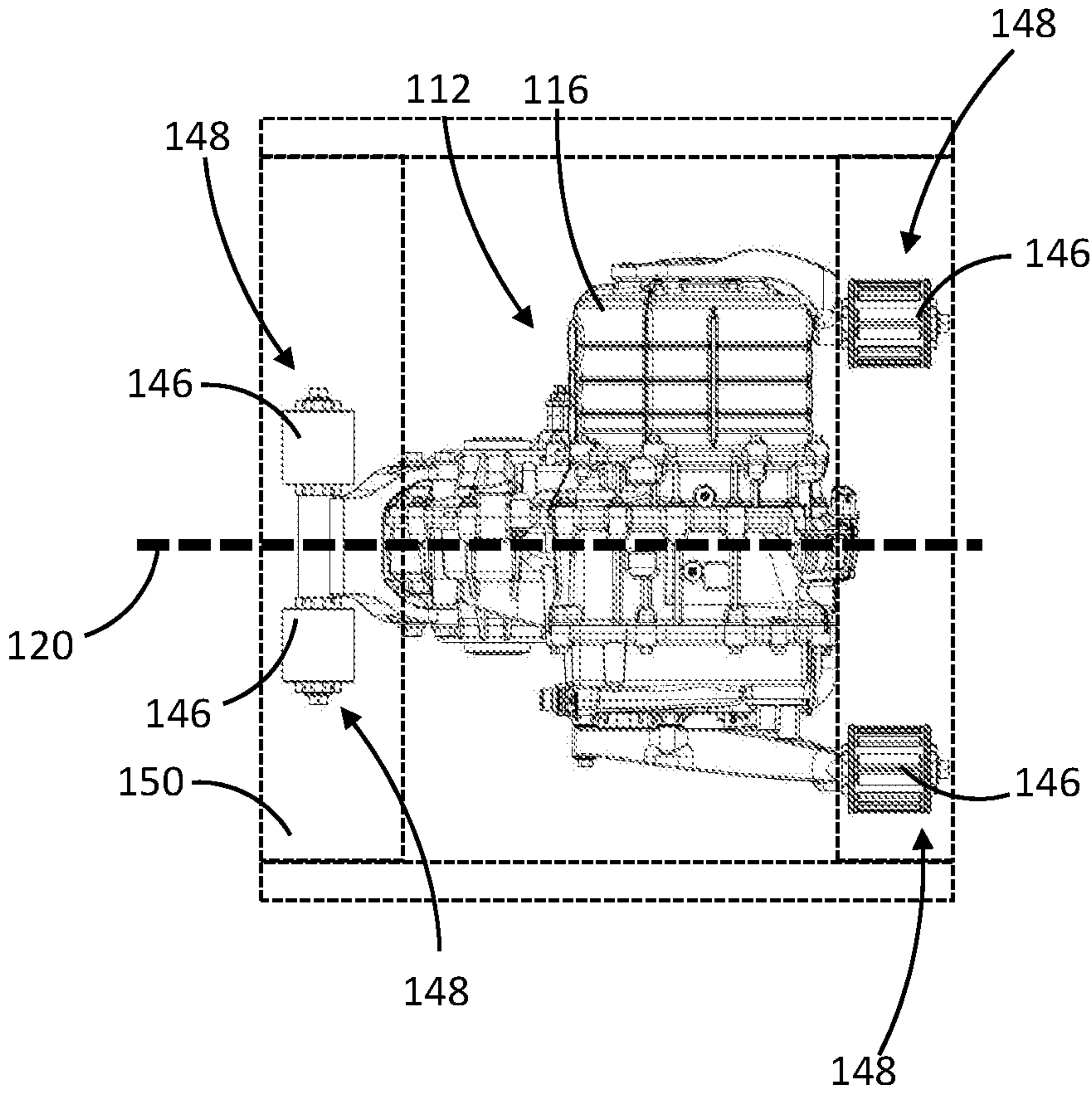


Figure 9

INTERNATIONAL SEARCH REPORT

International application No

PCT/GB2020/052558

A. CLASSIFICATION OF SUBJECT MATTER

INV. B60K1/00

ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B60K

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.
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Y	figures 1-6 -----	11
Y	US 2019/283560 A1 (SUZUKI TAKANORI [JP] ET AL) 19 September 2019 (2019-09-19) figures 1-3,6,7 -----	11
X	US 2018/290530 A1 (CHAI XU [CN] ET AL) 11 October 2018 (2018-10-11) figures 1,4 -----	1-6, 9-11,14



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

23 November 2020

Date of mailing of the international search report

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Eriksson, Jonas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2020/052558

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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