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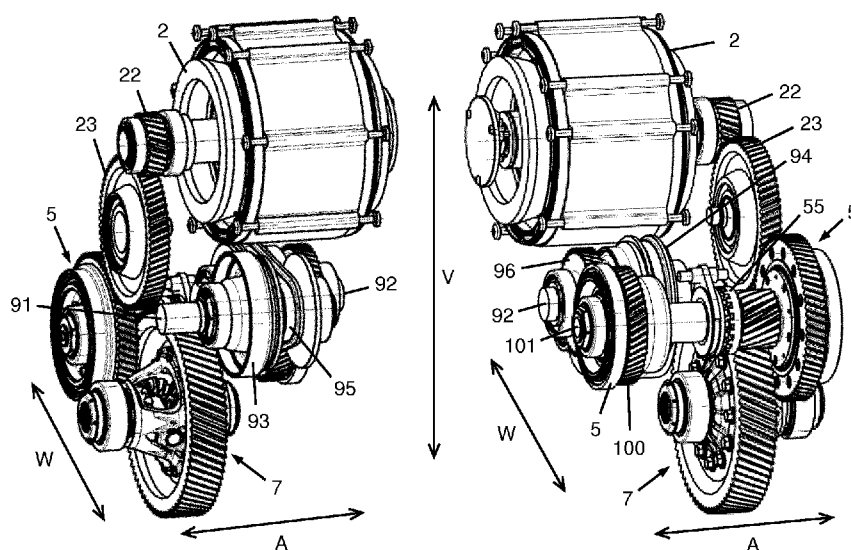


FIG. 2

(57) Abstract: A variable transmission (4) for a hybrid powertrain, in particular in a motor vehicle with an internal combustion engine (1) comprising a crankshaft (11), with an electric machine (2) comprising a rotor shaft (21) with a pinion gear (22), with a driven wheel (3) and with the variable transmission (4) provided there between, which variable transmission (4) includes a variator unit (9) with an input shaft (91) and an output shaft (92), whereof the input shaft (91) is intended to be driven by the internal combustion engine (1), for varying a transmission ratio between these shafts (91, 92), which variable transmission (4) further includes a differential gearing (5), wherein at least in an orientation of the variable transmission (4) as applied in the motor vehicle, the electric machine (2), or at least the rotor shaft (21) thereof, is located above the input shaft (91) and the output shaft (92) of the variator unit (9) in vertical direction and wherein the pinion gear (22) of the electric machine (2) is located on the same side of the variator unit (9) as the input shaft (91) thereof in axial direction.

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## VARIABLE TRANSMISSION FOR A HYBRID POWERTRAIN INCLUDING A VARIATOR UNIT AND A DIFFERENTIAL GEARING

The present disclosure relates to a variable transmission for or in a hybrid  
5 powertrain for a motor vehicle, in particular a passenger car with an internal  
combustion engine, i.e. ICE, with an electric machine or motor/generator device, i.e.  
EM, and with a driven wheel. The transmission includes a variator unit and a first  
differential gearing. The variator unit is provided for varying a speed ratio between an  
input shaft and an output shaft of the variator unit within a range of speed ratios. Such  
10 variator unit is well known in the art, most commonly in the form of two rotatable,  
variable pulleys, each associated with (i.e. mounted on and is possibly partly formed  
integral with) a respective one of the said input and output shafts, and a drive belt or  
chain that is wrapped around the pulleys for drivingly connecting these. The first  
differential gearing is provided with three, relatively rotatable members that respectively  
15 drivingly connect to either the ICE, the EM or the driven wheel. The first differential  
gearing serves to combine and/or distribute mechanical power between these three  
components during operation of the hybrid powertrain. In particular, a differential  
gearing balances the torque levels acting on its rotatable members, based on the  
rotational speed ratios provided there between. Such first differential gearing is well  
20 known in the art, most commonly in the form of an epicyclic differential or planetary  
gearing with a central sun gear that meshes with several individually rotatable  
planetary gears that are collectively born by a carrier that is rotatable coaxially with the  
sun gear, which planetary gears in turn mesh with a ring gear that is likewise coaxially  
rotatable with the sun gear. The carrier of the planetary gearing is drivingly connected  
25 to, i.e. rotates as a unit with the driven wheel, whereas the sun gear and the ring gear  
are respectively drivingly connected to, i.e. rotate as a unit with either the ICE or the  
EM respectively.

Such a hybrid powertrain provides for several operation modes of the motor  
vehicle, such as a battery-powered EM drive mode, a gasoline-powered ICE drive  
30 mode, a combined ICE and EM, i.e. hybrid drive mode, an EM brake energy  
recuperation, i.e. generation mode, an ICE to EM battery charge mode etc.

It is noted that, the variable transmission is preferably provided with a final  
reduction gearing including a further differential gearing between the first differential  
gearing and the driven wheel, such that two driven wheels of the motor vehicle can be  
35 simultaneously driven at different rotational speeds. Moreover, a first clutch is

preferably provided in the variable transmission to be able to lock a least two of the three members of the first differential gearing together, making all three such members rotate as a unit and thus providing a fixed-ratio drive connection between the EM and the driven wheel. Further, a second clutch is preferably provided in the variable  
5 transmission to be able to selectively couple, i.e. to selectively drivingly connect the ICE and the planetary gearing together, or to decouple these components from one another.

The above-described transmission is for example known from EP 0 941 883 A3 and US 6,054,776, at least in general. In both these known transmission designs, the  
10 variator unit is arranged between the planetary gearing and the driven wheel. The present disclosure, however, specifically relates and is limited to a transmission design wherein the variator unit is arranged between the planetary gearing and the ICE.

The known transmission has the drawback that it requires considerable installation space, i.e. occupies a relatively large volume, because the variator unit is  
15 fitted between the ICE and the planetary gearing, which planetary gearing -in turn- being fitted between the EM and the driven wheels. The present disclosure aims to mitigate such drawback and to provide for a favourably compact transmission design.

According to the present disclosure, the physical arrangement of the transmission's main components is considered separately from the above-described  
20 functional arrangement thereof. In particular according to the present disclosure:

- the EM is located above the input and output shafts of the variator unit as seen in the vertical direction when the transmission is mounted in the motor vehicle; and
- an output, i.e. pinion gear on a rotor shaft of the EM is located on the same axial side of the variator unit as the ICE, i.e. on the axial side of the input shaft of the  
25 variator unit that is attached to a crankshaft of the ICE.

By this physical arrangement of the said transmission components only a minimal installation space is required, not only in an axial direction, i.e. horizontally when mounted, but also perpendicular thereto, in particular vertically when mounted. By the said placement of the EM above the variator unit, the final reduction gearing can be  
30 favourably accommodated below the variator unit, i.e. in particular such that output shafts thereof are favourably located at a similar height as the axes of rotation of the driven wheels. A further improvement in the above respect is realised when the variator unit is oriented at an angle relative to the horizontal direction, in particular by its output shaft being located somewhat higher than its input shaft.

35 Alternatively or additionally according to the present disclosure, for also requiring

a minimal installation space perpendicular to the axial direction in the horizontal plane, i.e. in a width direction, the rotor shaft of the EM is preferably located between the input shaft and the output shaft of the variator unit as seen in that width direction. In other words, the rotor shaft of the EM is located between two (imaginary/virtual) vertical  
5 planes that each intersect a respective shaft of the variator unit.

Alternatively or additionally according to the present disclosure, an output gear on the output shaft of the variator unit can be favourably incorporated in the transmission, which output gear provides a speed reduction from the variator unit to the planetary gearing located there below. This latter speed reduction is desired to  
10 optimise the utilisation and, more in particular, the torque delivery of the ICE during operation of the hybrid powertrain. Moreover, such output gear enables a favourably compact transmission design, i.e. with minimal installation space, because the planetary gearing can thereby be arranged off-axis relative to the output shaft of the variator unit. In particular, by the thus provided flexibility in the placement of the  
15 planetary gearing, an idler gear can be optimally incorporated in the transmission between, i.e. as part of the driving connection between the EM and the planetary gearing, essentially irrespective of the speed reduction that is required therefor. In this respect, it is worth noting that the speed reduction of this latter driving connection and thus a diameter of the idler gear relative to the EM pinion gear can be relatively large.  
20 In particular, depending on a rotational speed range of the EM in question, a speed reduction ratio of 3:1 up to 4:1 or even more can be optimal in this respect. This speed reduction is desired to optimise the utilisation and, more in particular, the torque delivery of the EM during operation of the hybrid powertrain. According to the present disclosure, by additionally locating a central axis of the planetary gearing, i.e. an axis of  
25 rotation thereof, below the (central axis of rotation of the) input and output shafts of the variator unit as seen in the vertical direction, a relatively large idler gear can be favourably incorporated in the transmission between the EM and either the sun gear or the ring gear of the planetary summation gear. The idler gear serves to bridge the distance in the vertical direction between the EM the planetary gearing, and can help to  
30 accommodate the said, relatively large, speed reduction ratio from the EM to the planetary gearing.

In a preferred embodiment of the transmission in terms of the said physical arrangement of its main components, the planetary gearing is located on the same axial side of the variator unit as the pinion gear of the EM, whereas the output shaft of  
35 the variator unit is located on the opposite axial side thereof. By this arrangement, gear

trains that are located between, i.e. that drivingly connect the rotor shaft of the EM and the output shaft of the variator unit to the planetary gearing respectively, are favourably located on opposite axial sides of the variator unit. Hereby, the installation space is used very effectively. Moreover, an output of the transmission that is provided by the a  
5 final reduction is favourably located at the axial side of the transmission that faces the ICE, such that drive shafts extending from the a final reduction gearing to the driven wheels in the hybrid powertrain are of similar length, as is generally preferred.

More specifically in this preferred embodiment, an auxiliary gear associated with an auxiliary shaft is incorporated in the transmission, which auxiliary gear meshes with  
10 the output gear of the variator unit and which auxiliary shaft is coaxial with and drivingly connects to, i.e. rotates as a unit with either the sun gear or the ring gear of the planetary gearing. Preferably, the auxiliary gear is provided with a central opening with the auxiliary shaft extending through such opening, with the said second clutch arranged between the auxiliary shaft and the auxiliary gear on the axial side thereof  
15 that faces away from the planetary gearing. In this case, preferably, a radial bearing is fitted on, i.e. around the auxiliary shaft and inside the central opening of the auxiliary gear. These latter, preferred embodiments, further reduce the required installation space of the transmission. For example, the output shaft of the variator unit does not interfere with the second clutch that can thus be optimally incorporated in the  
20 transmission. In particular, the second clutch can be provided with a relatively large diameter, favourably reducing the number of sets of friction plates required in a plate clutch and/or favourably enabling a cone clutch to be applied instead. Moreover, when the second clutch is opened during operation of the hybrid powertrain, i.e. when the variator unit is decoupled from the planetary gearing so that the ICE can be  
25 stopped/switch-off, also the auxiliary gear and the output gear are decoupled and favourably stop rotating as well.

Even more specifically in this latter preferred embodiment, the ring gear of the planetary gearing is preferably drivingly connected to the EM, e.g. by meshing with the said idler gear, and the sun gear of the planetary gearing is preferably drivingly  
30 connected to the ICE, e.g. by being as part of, mounted on or otherwise attached to the auxiliary shaft. Additionally in this case, the carrier of the planetary gearing is preferably located on the same axial side of the planetary gearing as the auxiliary gear, with the auxiliary shaft extending through a central opening of the carrier. By this latter measure, the final reduction gearing that is drivingly connected to the carrier, is  
35 optimally positioned in the axial direction, essentially midway between the drive wheels,

at least in case the ICE is transversely mounted in the motor vehicle.

If, alternatively, the ring gear of the planetary gearing is drivingly connected to the ICE and the sun gear of the planetary gearing is drivingly connected to the EM, then the EM is still located above the input and output shafts of the variator unit as seen in the vertical direction and the pinion gear on the rotor shaft of the EM is still located on the same axial side of the variator unit as the ICE. However, in this case, it can be opted to locate the planetary gearing on the opposite axial side of the variator unit as the pinion gear of the EM instead. Moreover, the auxiliary shaft extends from the planetary gearing, where it carries or at least rotates as a unit with the sun gear, to the other axial side of the variator unit, where it is drivingly connected to the electric machine via one more auxiliary and/or idles gears. Additionally in this case, the carrier of the planetary gearing is preferably provided with a central opening where through the auxiliary shaft extends.

The variable transmission according to the present disclosure is explained in more detail hereinafter by means of non-limiting, illustrative embodiments thereof and with reference to the drawing, in which:

- figure 1 is a schematic representation of the functional arrangement of the main components of a specific type hybrid powertrain provided with a transmission;
- figure 2 provides a 3D model of a physical arrangement of the internal components of the transmission in accordance with the present disclosure as seen in two different directions;
- figure 3 is a schematic, partial side elevation of the physical transmission arrangement of figure 2, illustrating a specific aspect thereof;
- figure 4 provides a schematic representation of another specific aspect of the physical transmission arrangement of figure 2;
- figure 5 provides a schematic representation of another transmission arrangement;
- figure 6 provides a detail of a part of the transmission arrangement of figure 5;
- figure 7 provides a schematic representation of another transmission arrangement; and
- figure 8 provides a schematic representation of yet another transmission arrangement.

Figure 1 shows a hybrid powertrain for a motor vehicle such as a passenger car. In such shown functional arrangement thereof, the hybrid powertrain comprises an internal combustion engine, i.e. ICE 1, with a crankshaft 11, an electric machine, i.e. EM 2, with a rotor shaft 21, two driven wheels 3 with wheel shafts 31 and with a

variable transmission 4 there between. The known transmission 4 comprises a variator unit 9 and a first differential gearing 5. The variator unit 9 is provided with an input shaft 91 that is drivingly connected to, i.e. that rotates as a unit with the ICE 1 and with an output shaft 92. The variator unit 9 can vary a speed ratio between an input shaft 91  
5 and an output shaft 92 thereof within a continuous range of speed ratios.

In the illustrative embodiment thereof in figure 1, the variator unit 9 is in the form of two rotatable, variable pulleys 93 and 94, each associated with (i.e. mounted on and is possibly partly formed integral with) a respective one of the said input and output shafts 91 and 92, and a drive belt or chain 95 that is wrapped around the pulleys 93  
10 and 94 for drivingly connecting these.

The first differential gearing 5 is provided with three rotatable members 51, 54, 53 that are respectively drivingly connected to, i.e. rotate as a unit with the output shaft 92 of the variator unit 9, the rotor shaft 21 of the EM 2 and the wheel shafts 31 of the driven wheels 3. The first differential gearing 5 balances the torque levels acting on its  
15 rotatable members 51, 54, 53, based on the rotational speed ratios provided there between.

In the illustrative embodiment thereof in figure 1, the first differential gearing 5 is in the form of a planetary gearing 5 provided with a central sun gear 51 that is in meshing contact with one or more planet gears 52, which planet gears 52 are rotatably  
20 carried by a planet carrier 53 arranged coaxially rotatable with the sun gear 51, and with a ring gear 54 that is in meshing contact with the planet gears 52 and that is also arranged coaxially rotatable with the sun gear 51. A bridging clutch 55 is provided as part of planetary gearing 5, between the planet carrier 53 and sun gear 51 thereof. This bridging clutch 55 can be closed to internally lock the planetary gearing 5 such  
25 that the sun gear 51, the planet carrier 53 and the ring gear 54 thereof rotate as a unit.

The sun gear 51 of the planetary gearing 5 is coupled to the crankshaft 11 of the ICE 1 via a second clutch 8, an auxiliary gear 100 on an auxiliary shaft 101, an output gear 96 on the output shaft 92 meshing with that auxiliary gear 100 and the variator unit 9 itself. The second clutch can be selectively closed to drivingly connecting, i.e. to  
30 couple the ICE 1 and the variator unit 9 to the planetary gearing 5, or opened to decouple, i.e. to isolate the ICE 1 and the variator unit 9 from the rest of the hybrid powertrain. The ring gear 54 of the planetary gearing 5 is coupled to a pinion gear 22 on the rotor shaft 21 of the EM machine 2 via an idler gear 23 and the planet carrier 53 of the planetary gearing 5 is coupled to the driven wheels 3 via a final reduction  
35 gearing 7 including a further differential gearing 71. The final reduction gearing 7

provides a speed reduction between the ICE 1 and/or the EM 2 and the driven wheels 3, while the further differential gearing 71 thereof allows the two driven wheels 3 to each rotate at a respective rotational speed, as is common knowledge in the art.

The transmission 4 is provided with a brake or park lock 6 that can be engaged  
5 to lock, i.e. to prevent rotation of the final reduction gearing 7, in which case the ICE 1 can drive the EM 2, in particular to charge a battery 24 of the motor vehicle, or the EM 2 can drive the ICE 1, in particular to start it, without simultaneously driving and/or rotating the driven wheels 3 of the motor vehicle. When the park lock 6 is released, the EM 2 can drive the motor vehicle while drawing electric power from the battery 24,  
10 possibly supported by the ICE 1. Instead of the park lock 6 it is of course also possible to (automatically) engage the vehicle wheel brakes to charge the battery 24 without simultaneously driving the vehicle.

Further technical details of this particular type of hybrid powertrain, as well as the specific benefits and operations thereof, are described in the Dutch patent NL1042199.

15 According to the present disclosure, it is generally to be preferred that the transmission 4 occupies only a relatively small installation space. Figure 2 provide such a preferred embodiment of the transmission 4 by the physical arrangement of the main components thereof in accordance with the present disclosure in two 3D views thereof and relative to a mounted position thereof in the motor vehicle.

20 The transmission 4 of figure 2 incorporates the following design features in accordance with the present disclosure that provide for a compact physical realisation thereof:

- the EM 2 is located above the input shaft 91 and the output shaft 92 of the variator unit 9 as seen in a vertical direction V;
- 25 - the pinion gear 22 of the EM 2 is located on the same side of the variator unit 9 as the input shaft 91 thereof relative to an axial direction A;
- the rotor shaft 21 of the EM 2 is located between the input shaft 91 and the output shaft 92 of the variator unit 9 in a width direction W;
- the rotor shaft 21 of the EM 2 is located between the input shaft 91 and the output  
30 shaft 92 of the variator unit 9 in a width direction W;
- the planetary gearing 5 is located on the same side of the variator unit 9 as the pinion gear 22 of the EM 2 relative to the axial direction A,
- the idler gear 23 drivingly connecting the planetary gearing 5 to the EM 2 and the auxiliary gear 100 drivingly connecting the planetary gearing 5 to the ICE 1 (via the  
35 variator unit 9) are mounted on mutually opposite sides of the variator unit 9 relative

to the axial direction A.

Figure 3 elucidates a further design aspect of the novel physical transmission arrangement of figure 2. Figure 3 shows two instances of a mutual positioning of four transmission components, namely the EM 2, the variator unit input pulley 93, the  
5 variator unit output pulley and the final reduction gearing 7, and then only schematically in a side elevation of thereof. On the left side of figure 3, the input pulley 93 and the output pulley lie in the same horizontal plane HP that is defined by the said width and axial directions. On the right side of figure 3, however, the variator unit 9 is oriented at an angle relative to the horizontal plane HP by an axis of rotation of its output shaft 92  
10 being located higher than that of its input shaft 91 in the vertical direction V, which latter mutual positioning corresponds to that of the figure 2. From figure 3, it appears that such angled orientation of the variator unit 9 significantly reduces the installation space required for the said transmission components in the vertical direction V, albeit at the expense of the somewhat increased installation space in the width direction W.  
15 In particular, by such angled orientation of the variator unit 9 and by locating the EM 2 closer to the axis of rotation of the input pulley 93 than to the axis rotation of the output pulley 94 in the width direction W, the EM 2 can also be located lower in the vertical direction.

It is noted that in the present transmission arrangement the speed ratio range of  
20 the variator unit 9 can be comparatively limited, since the total speed ratio range of the transmission 4 is extended by the planetary gearing 5. A so-called ratio coverage (defined as the largest achievable speed ratio divided by the smallest achievable speed ratio) of the variator unit 9 needs to be between 3.0 and 4.5 only, compared to around 7.0 in a more conventional transmission arrangement without the planetary  
25 gearing 5. This latter aspect too helps to reduce the required installation space and, in particular, enables to take full advantage of the angled orientation of the variator unit 9 in this respect.

Moreover, by locating the final reduction gearing 7 closer to the axis of the output pulley 94 than to the axis of the input pulley 93 in the width direction W, the final  
30 reduction gearing 7 can also be located higher in the vertical direction. As a result, a diagonal distance between the axis of rotation of the input shaft 91 of the variator unit 9, which corresponds to the axis of rotation of the crank shaft 11 of the ICE 1, and that of the final reduction gearing 7 is remarkably reduced. Such reduction is considered highly advantageous, since especially this diagonal distance typically determines -and  
35 set a minimum for- the installation space required for the so-called engine bay of the

motor vehicle.

Although not shown in figure 3, the final reduction gearing 7 can -and, in the transmission arrangement of figure 2, does- partially overlap with the output pulley 94 in the vertical direction. For the EM 2 a corresponding vertical overlap with the input pulley 93 is, however, not possible due to its considerable size in the axial direction. In this case too, in order to further optimise the overall installation space of the transmission 4, the axis of rotation of the EM 2, i.e. of its rotor shaft 21, is located close to, but still on the same side of the axis of the input pulley 93, i.e. the input shaft 91, at the axis of the output pulley 94, i.e. the output shaft 92.

Figure 4 illustrates yet a further design aspect of the novel physical transmission arrangement of figure 2 in a schematically drawn, physical arrangement thereof. In particular in figure 4, the auxiliary gear 100 is provided with a central opening, with the auxiliary shaft 101 extending through such opening, and with the said second clutch 8 embodied as a friction clutch and arranged between the auxiliary shaft 101 and the auxiliary gear 100 on the axial side thereof that faces away from the planetary gearing 5; 51-54. As a result, the said second clutch 8 interferes neither with the variator output shaft 92, nor with the auxiliary shaft 101. Therefore, the said second clutch 8 can favourably be provided with a relatively large diameter.

Alternatively, but not illustrated, the said second clutch 8 can be integrated in radial direction between the auxiliary shaft 101 and the auxiliary gear 100, which is feasible if the said second clutch 8 is embodied as a dry-friction, cone clutch. Indeed, the required slip-torque capacity of this clutch 8 is relatively low, because it does not serve as a starting clutch for the initial acceleration of the motor vehicle from standstill, but merely serves to start the ICE 1 when the operation of the transmission switches from a purely electric drive mode to a hybrid, i.e. ICE assisted drive mode.

Also in figure 4 the bridging clutch 55 is embodied as an interference clutch (also known as a dog clutch) that is favourably simple in construction and control as compared to a friction clutch. Of course, in this case, the torque and speed of the components 51-54 of the planetary gearing 5 is equalised (by the appropriate control of the ICE 1, the EM 2 and the variator unit 9).

Further, in figure 4 the carrier 53 of the planetary gearing 5; 51-54 is incorporated in the transmission 4 on the axial side of the planet gears 52 facing away from the ICE 1 and as a hollow gear provided with a central opening, with the auxiliary shaft 101 extending through it. As a result, the final reduction gearing 7 that is drivingly connected to the carrier 53 is optimally positioned in axial direction relative to the

driven wheels 3.

Figure 5 illustrates an alternative arrangement of the novel transmission. In this alternative transmission arrangement, the said second clutch 8 is arranged on the auxiliary shaft 101 between the bridging clutch 55 and the planetary gearing 5; 51-54 that are arranged on the respective ends of that auxiliary shaft 101. A connecting shaft 102 is provided between the bridging clutch 55 and the planetary gearing 5; 51-54. The connecting shaft 102 is provided coaxially with the auxiliary shaft 101, where to the latter is embodied as a hollow shaft with a central opening, with the connection shaft 102 extending through it. An advantage of this particular arrangement is that the bridging clutch 55 and the planetary gearing 5; 51-54 are provided on either end of the auxiliary shaft 101 and the connecting shaft 102, such that any (torque) shocks resulting from a closing or opening of the bridging clutch 55 are dampened by a twisting of these shafts 101, 102. Such dampening effect can be enhanced by providing the connecting shaft 102 as a hollow shaft over at least a substantial part of its length. However, preferably, the connecting shaft 102 is provided as a hollow shaft over a predominant part of its length, as illustrated in figure 6.

The alternative arrangement of the transmission 4 of figure 5 is particularly suitable if the said second clutch 8 has a relatively small diameter, such as when it is integrated in radial direction between the auxiliary shaft 101 and the auxiliary gear 100 as mentioned hereinabove. In this case a favourably compact build of the transmission 4 can be achieved, both in the axial direction and in the height/radial direction.

In the figures 1 to 6, the first differential gearing 5 of the transmission 4 is embodied as a planetary gearing 5 whereof the sun gear 51 is driven by the ICE 1 and the ring gear 54 is driven by (or drives) the EM 2. This specific embodiment of the first differential gearing 5 is particularly suited for a powerful EM 2 with a high (maximum) torque generating capability, in particular exceeding the maximum torque of the ICE 1, e.g. by more than 25%. However, if the maximum EM torque is comparable to, or less than the maximum ICE torque, it is preferable to either embody the first differential gearing 5 with two side gears 56, 57 of equal diameter, as schematically illustrated in figure 7, or to arrange it as a planetary gearing 5 with the ICE 1 driving the ring gear 54 and with the EM 2 driving (or being driven by) the sun gear 51, as schematically illustrated in figure 8. In either one of such alternative transmission embodiments, the EM 2 is still located above the input and output shafts 91, 92 of the variator unit 9 as seen in the vertical direction and the pinion gear 22 on the rotor shaft 21 of the EM 2 is still located on the same axial side of the variator unit 9 as the ICE 1.

In the embodiment of figure 8 thereof, the carrier 53 of the planetary gearing 5 is incorporated in the transmission 4 on the axial side of the planet gears 52 facing towards the ICE 1 and is embodied as a hollow gear provided with a central opening, with a shaft of the sun gear 51 extending through it. As a result, the final reduction 5 gearing 7 that is drivingly connected to the carrier 53 is optimally positioned in axial direction relative to the driven wheels 3 in this latter transmission embodiment as well.

The present disclosure, in addition to the entirety of the preceding description and all details of the accompanying figures, also concerns and includes all of the features in the appended set of claims. Bracketed references in the claims do not limit 10 the scope thereof, but merely provide a non-limiting example of a respective feature. Separately claimed features can be applied separately in a given product or a given process, as the case may be, but can also be applied simultaneously therein in any combination of two or more of such features.

The invention(s) represented by the present disclosure is (are) not limited to the 15 embodiments and/or the examples that are explicitly mentioned herein, but also encompass(es) straightforward amendments, modifications and practical applications thereof, in particular those that lie within reach of the person skilled in the relevant art.

## CLAIMS

1. A variable transmission (4) for a hybrid powertrain, in particular in a motor vehicle with an internal combustion engine (1) comprising a crankshaft (11), with an electric machine (2) comprising a rotor shaft (21) with a pinion gear (22), with a driven wheel (3) and with the variable transmission (4) provided there between, which variable transmission (4) includes a variator unit (9) with an input shaft (91) and an output shaft (92), whereof the input shaft (91) is intended to be driven by the internal combustion engine (1), for varying a transmission ratio between these shafts (91, 92), which variable transmission (4) further includes a differential gearing (5), characterized in that, at least in an orientation of the variable transmission (4) as applied in the motor vehicle, the electric machine (2), or at least the rotor shaft (21) thereof, is located above the input shaft (91) and the output shaft (92) of the variator unit (9) in vertical direction and in that the pinion gear (22) of the electric machine (2) is located on the same side of the variator unit (9) as the input shaft (91) thereof in axial direction.
2. The variable transmission (4) according to the claim 1, characterized in that the variator unit (9) is oriented under an angle with the horizontal plane, in particular with its output shaft (92), or at least the axis of rotation thereof, being located above its input shaft (91), or at least the axis of rotation thereof, in vertical direction.
3. The variable transmission (4) according to the claim 1 or 2, characterized in that the rotor shaft (21), or at least the axis of rotation thereof, is located between the input shaft (91) and the output shaft (92) of the variator unit (9), or at least the axes of rotation thereof in width direction.
4. The variable transmission (4) according to the claim 1, 2 or 3, characterized in that the differential gearing (5), or at least a central axis of rotation thereof, is located below the variator unit (9) in vertical direction.
5. The variable transmission (4) according to a preceding claim, characterized in that an idler gear (23) is included therein between the pinion gear (22) of the electric machine (2) and the differential gearing (5).
6. The variable transmission (4) according to a preceding claim, characterized in that the differential gearing (5) is located on the same side of the variator unit (9) as the

pinion gear (22) of the electric machine (2) in axial direction, in that the output shaft (92) of the variator unit (9) is provided with a an output gear (96), in that the output gear (96) is located on the opposite side of the variator unit (9) as the input shaft (92) thereof in axial direction and in that between the variator unit (9) and the differential gearing (5) the  
5 variable transmission (4) is provided with an auxiliary gear (100), with an auxiliary shaft (101) and with a releasable clutch (8), which auxiliary gear (100) meshes with the output gear (96) of the variator unit (9) and which releasable clutch (8) is arranged between the auxiliary gear (100) and the auxiliary shaft (101) that is connected to the differential gearing (5).

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7. The variable transmission (4) according to the claim 6, characterized in that the releasable clutch (8) is located on the side of the auxiliary gear (100) that faces away from the variator unit (9), in that the auxiliary gear (100) is provided with a central opening and in that the auxiliary shaft (101) extends through that central opening of the  
15 auxiliary gear (100).

8. The variable transmission (4) according to one of the claims 1-5, characterized in that the differential gearing (5) is located on the same side of the variator unit (9) as the pinion gear (22) of the electric machine (2) in axial direction, in that the output shaft (92)  
20 of the variator unit (9) is provided with a an output gear (96), in that the output gear (96) is located on the same side of the variator unit (9) as the input shaft (92) thereof in axial direction and in that between the variator unit (9) and the differential gearing (5) the variable transmission (4) is provided with an auxiliary gear (100), with an auxiliary shaft (101) connected to the differential gearing (5) and with a releasable clutch (8), which  
25 auxiliary gear (100) meshes with the output gear (96) of the variator unit (9) and which releasable clutch (8) is arranged between the auxiliary gear (100) and the auxiliary shaft (101).

9. The variable transmission (4) according to the claim 8, characterized in that the  
30 differential gearing (5) is provided with a bridging clutch (55) between the auxiliary shaft (101) and a further, connecting shaft (102) that is also connected to the differential gearing (5), which bridging clutch (55) is capable of internally locking the differential gearing (5) and which bridging clutch (55) is located on the side of the auxiliary gear (100) that faces away from the differential gearing (5), in that the auxiliary gear (100) is  
35 provided with a central opening and in that the auxiliary shaft (101) and the connecting shaft (102) extend through that central opening of the auxiliary gear (100).

10. The variable transmission (4) according to the claim 9, characterized in that the auxiliary shaft (101) is embodied as a hollow shaft with the connection shaft 102 extending through it.

5 11. The variable transmission (4) according to a preceding claim, characterized in that the differential gearing (5) is provided with three rotatable members (51, 54, 53) that are respectively drivingly connected to, i.e. rotate as a unit with either the output shaft (92) of the variator unit (9), the rotor shaft (21) of the electric machine (2) or the driven wheel (3).

10

12. The variable transmission (4) according to a preceding claim, characterized in that the differential gearing (5) is embodied as a planetary gearing (5) with a central sun gear (51) that meshes with several individually rotatable planetary gears (52) that are collectively born by a carrier (53) that is rotatable coaxially with the sun gear (51), which  
15 planetary gears (52) in turn mesh with a ring gear (54) that is likewise coaxially rotatable with the sun gear (51).

13. A hybrid powertrain with an internal combustion engine (1), with an electric machine (2), with a driven wheel (3) and with the variable transmission (4) according to  
20 the claim 12, characterized in that the carrier (53) of planetary gearing (5) is drivingly connected to, i.e. rotate as a unit with the driven wheel (3), in that the sun gear (51) of the planetary gearing (5) is drivingly connected to, i.e. rotate as a unit with the internal combustion engine (1), in that the ring gear (54) of the planetary gearing (5) is drivingly connected to, i.e. rotate as a unit with the electric machine (2) and in that, during  
25 operation of the hybrid powertrain, a first drive torque that can maximally be generated by the electric machine (2) on the ring gear (54) is higher than a second drive torque that can maximally be generated by the internal combustion engine (1) on the sun gear (51).

14. A hybrid powertrain with an internal combustion engine (1), with an electric machine (2), with a driven wheel (3) and with the variable transmission (4) according to  
30 the claim 12, characterized in that the carrier (53) of planetary gearing (5) is drivingly connected to, i.e. rotate as a unit with the driven wheel (3), in that the sun gear (51) of the planetary gearing (5) is drivingly connected to, i.e. rotate as a unit with the electric machine (2), in that the ring gear (54) of the planetary gearing (5) is drivingly connected  
35 to, i.e. rotate as a unit with the internal combustion engine (1) and in that, during operation of the hybrid powertrain, a first drive torque that can maximally be generated

by the internal combustion engine(1) on the ring gear (54) is higher than a second drive torque that can maximally be generated by the electric machine (2) on the sun gear (51).

15 15. The hybrid powertrain according to the claim 13 or 14, characterized in that the said first drive torque is at least 15% larger and preferably is at least 25% than the said first drive torque.

10 16. A hybrid powertrain with an internal combustion engine (1), with an electric machine (2), with a driven wheel (3) and with the variable transmission (4) according to the claim 11, characterized in that two of the said three rotatable members (51, 54, 53) of the differential gearing (5) are embodied as two side gears (56, 57) of equal diameter that are respectively drivingly connected to, i.e. rotate as a unit with the internal combustion engine (1) and the electric machine (2) and that are both in meshing contact with several individually rotatable planetary gears (52) that are collectively born by a  
15 carrier (53) that is drivingly connected to, i.e. rotate as a unit with the driven wheel (3), and in that, during operation of the hybrid powertrain, a drive torque that can maximally be generated by the internal combustion engine(1) on one (57) of the side gears (56, 57) and a drive torque that can maximally be generated by the electric machine (2) on the other one (56) of the side gears (56, 57) correspond to one another within a margin of  
20 25%, preferably within a margin of 15%.

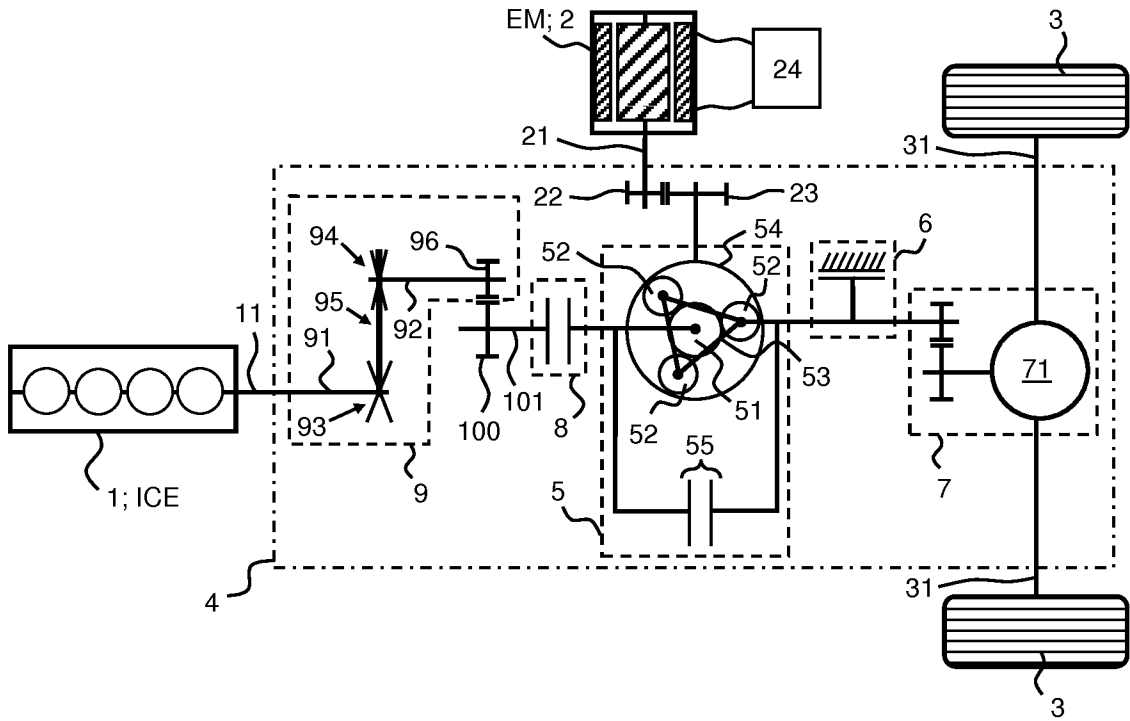


FIG. 1

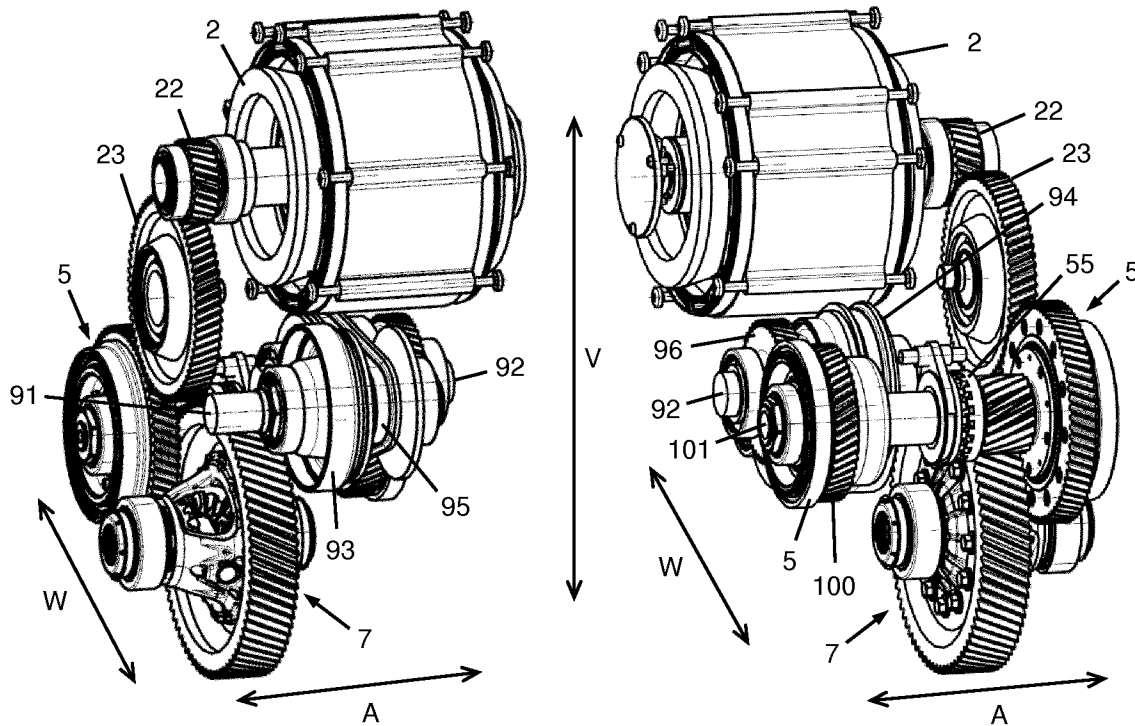


FIG. 2

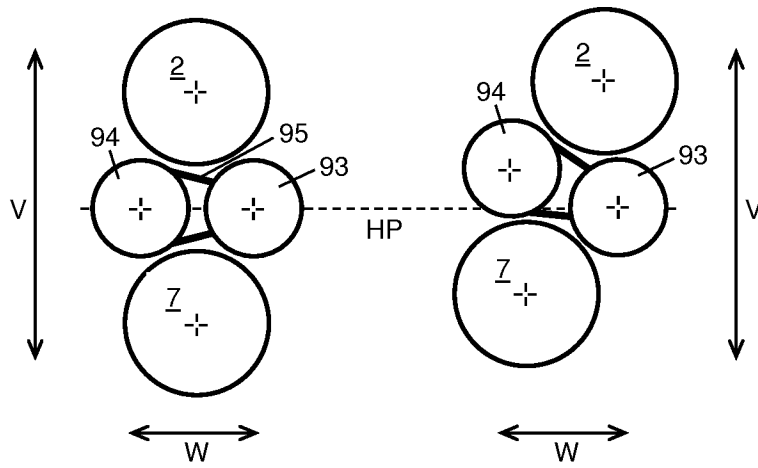


FIG. 3

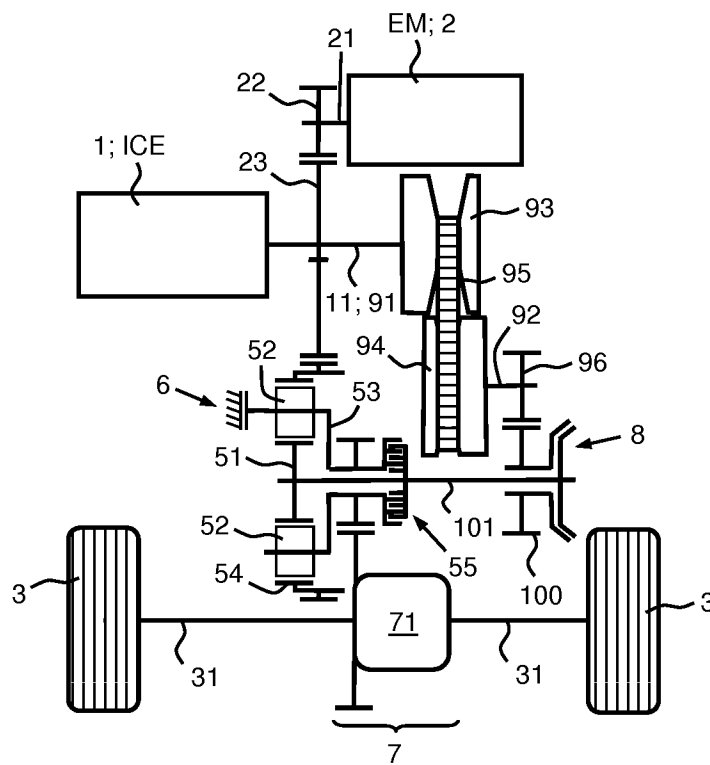


FIG. 4

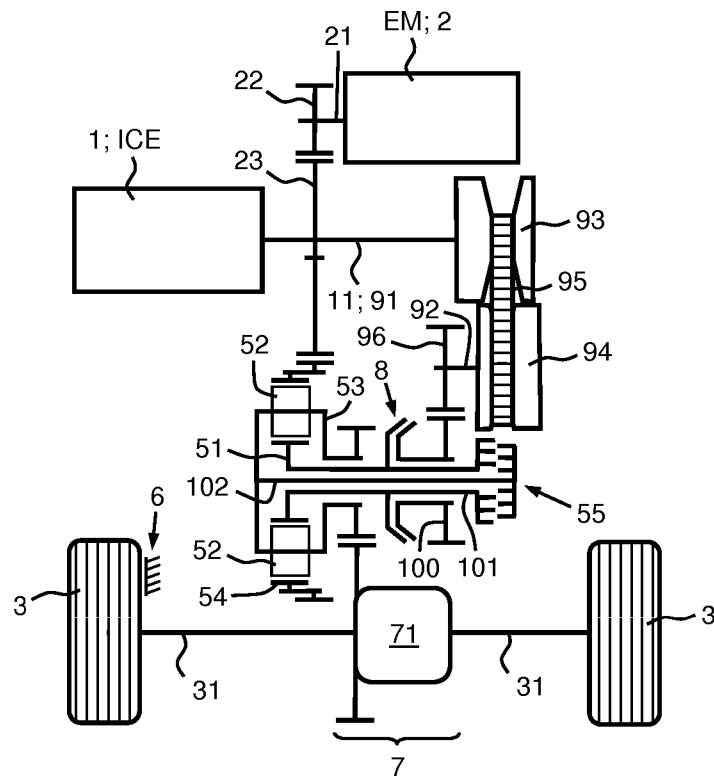


FIG. 5

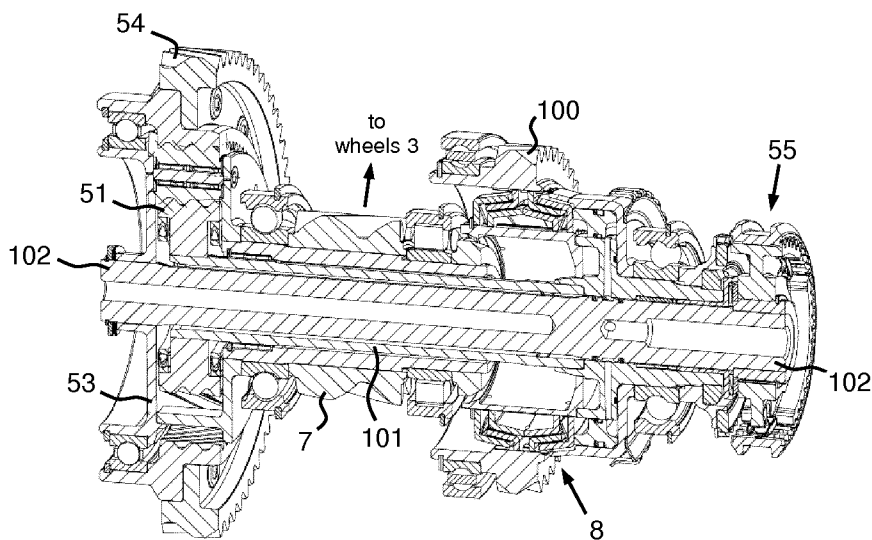


FIG. 6

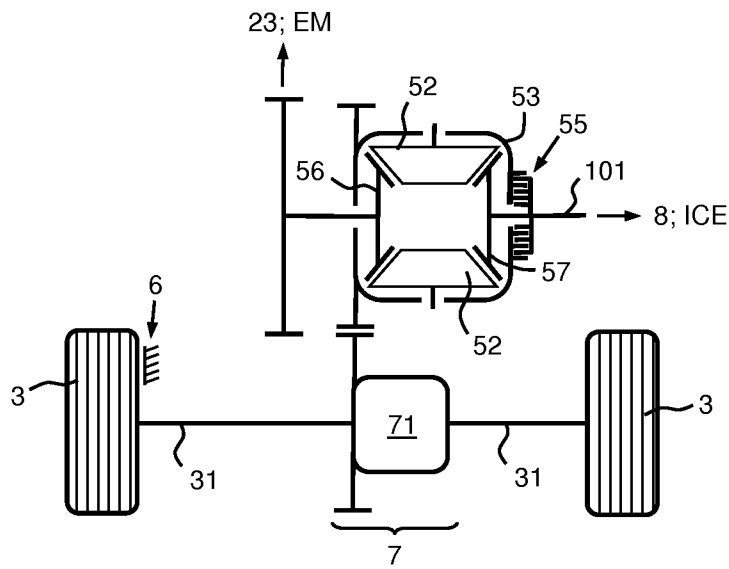


FIG. 7

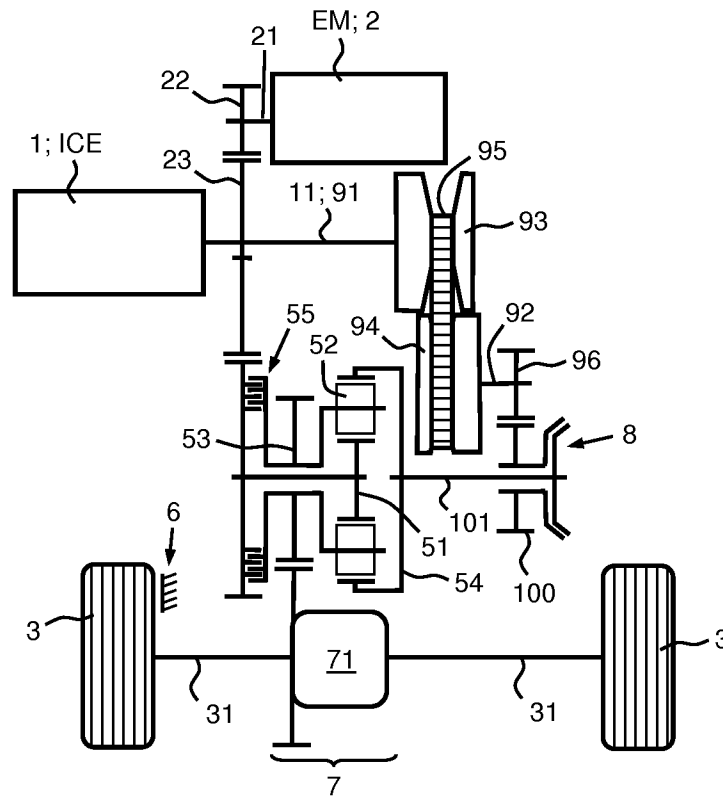


FIG. 8

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/EP2019/025194

A. CLASSIFICATION OF SUBJECT MATTER  
 INV. B60K6/48 B60K6/365 B60K6/543 B60K6/40  
 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.
X	JP 2009 001126 A (TOYOTA MOTOR CORP) 8 January 2009 (2009-01-08)	1-5
A	paragraph [0052]; figures 1-5	6-16
A	----- WO 2015/059252 A1 (CESARONI ANTONIO FRANCISCO [IT]) 30 April 2015 (2015-04-30) page 5, line 30 - page 10, line 26; figure 2	1,11-16
A	----- US 6 344 008 B1 (NAGANO SHUJI [JP] ET AL) 5 February 2002 (2002-02-05) column 3, line 49 - column 5, line 22; figures 1,11-16	1
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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
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- "O" document referring to an oral disclosure, use, exhibition or other means
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- "&" document member of the same patent family

Date of the actual completion of the international search  22 October 2019	Date of mailing of the international search report  04/11/2019
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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  Wurzer, Oliver
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2019/025194
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2009001126	A	08-01-2009	NONE
WO 2015059252	A1	30-04-2015	CA 2927950 A1 30-04-2015
			CN 105848949 A 10-08-2016
			EP 3060421 A1 31-08-2016
			ES 2699784 T3 12-02-2019
			JP 6571096 B2 04-09-2019
			JP 2017500518 A 05-01-2017
			KR 20160089372 A 27-07-2016
			RU 2016119352 A 28-11-2017
			RU 2018128000 A 14-03-2019
			US 2016257192 A1 08-09-2016
			WO 2015059252 A1 30-04-2015
US 6344008	B1	05-02-2002	DE 10036966 A1 05-04-2001
			JP 3817982 B2 06-09-2006
			JP 2001047881 A 20-02-2001
			US 6344008 B1 05-02-2002