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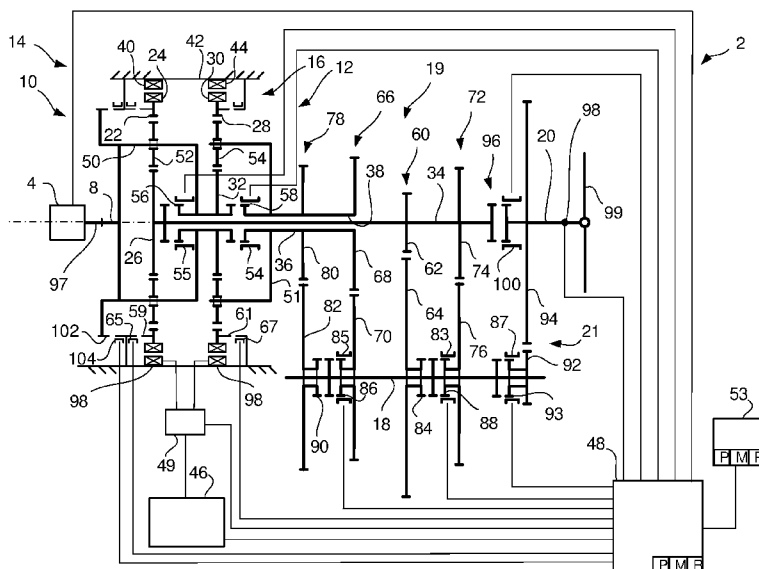


Fig. 2

(57) Abstract: The invention concerns a gearbox comprising an input shaft (8) and an output shaft (20); a first epicyclic gear (10) that is connected to the input shaft (8); a second epicyclic gear (12) that is connected to the first epicyclic gear (10); a first electrical machine (14) that is connected to the first epicyclic gear (10); a second electrical machine (16) that is connected to the second epicyclic gear (12); a first gear pair (60) that is arranged between the first epicyclic gear (10) and the output shaft (20); and a second gear pair (66) that is arranged between the second epicyclic gear (12) and the output shaft (20). A side shaft (18) is arranged between the relevant first and second epicyclic gear (10, 12) and the output shaft (20); that the side shaft (18) is connected to the output shaft (20) through a final gear (21); and that the final gear (21) comprises a gear element (92), that is arranged at the side shaft (18) in a manner that allows it to be disengaged. The invention concerns also a vehicle (1) that comprises such a gearbox (2), and a method to control such a gearbox (2). The invention

concerns also a computer program (P) to control a gearbox, and a computer program product comprising program code for an electronic control unit (48) or another computer (53) in order to implement the method according to the invention.

WO 2014/158074 A1

Gearbox for a hybrid powertrain and method to control such a gearbox

5 BACKGROUND AND PRIOR ART

The present invention concerns a gearbox according to the introduction to claim 1. The invention concerns also a vehicle that comprises such a gearbox according to the introduction to claim 14, a method to control such a gearbox according to the introduction to claim 15, a
10 computer program to control such a gearbox according to the introduction to claim 19, and a computer program product comprising program code according to the introduction to claim 20.

Hybrid vehicles can be driven by a primary engine, which may be a combustion engine, and a
15 secondary engine, which may be an electrical machine. The electrical machine is equipped with at least one energy store, such as an electrochemical energy store, for the storage of electrical energy, and regulating equipment in order to regulate the flow of electrical energy between the energy store and the electrical machine. The electrical machine can in this way alternate between working as an engine and as a generator, depending on the operating condi-
20 tion of the vehicle. When the vehicle is braked, the electrical machine generates electrical energy, which is stored in the energy store. This is generally known as “regenerative braking”, and it leads to the vehicle being braked with the aid of the electrical machine and the combustion engine. The electrical energy that is stored is later used for the operation of the vehicle.

25 An epicyclic gear normally comprises three components that are arranged in a manner that allows rotation relative to each other. These components are a sun gear, a planet wheel carrier and a ring gear. Knowledge of the numbers of teeth on the sun gear and ring gear allows the mutual rates of revolution of the three components to be determined during operation. One of
30 the components of the epicyclic gear may be connected to an output shaft of a combustion engine. Thus this component of the epicyclic gear rotates with a rate of revolution that corresponds to the rate of revolution of the output shaft of the combustion engine. A second component of the epicyclic gear may be connected to an input shaft to a gearbox. Thus this component of the epicyclic gear rotates with the same rate of revolution as the input shaft to the

gearbox. A third component of the epicyclic gear is connected to a rotor of an electrical machine, in order to achieve hybrid operation. Thus this component of the epicyclic gear rotates with the same rate of revolution as the rotor of the electrical machine, if they are directly connected to each other. Alternatively, the electrical machine may be connected to the third component of the epicyclic gear through a transmission that has a gear exchange. In this case, the electrical machine and the third component of the epicyclic gear may rotate with different rates of revolution. At least one of the rate of revolution and the torque developed by electrical machines may be regulated in stepless increments. During operation, when the input shaft to the gearbox is to be given at least one of a desired rate of revolution and torque, a control unit calculates, given knowledge of the rate of revolution of the combustion engine, the rate of revolution with which the third component must be driven in order for the input shaft to the gearbox to be given the desired rate of revolution. A control unit activates the electrical machine such that it gives the calculated rate of revolution to the third component, and thus gives the desired rate of revolution to the input shaft to the gearbox.

15

By connecting together the output shaft of the combustion engine, the rotor of the electrical machine and the input shaft to the gearbox using an epicyclic gear, the conventional clutch mechanism can be avoided. During acceleration of the vehicle, increased torque is to be supplied from the combustion engine and the electrical machine to the gearbox and onwards to the driving wheels of the vehicle. Since both the combustion engine and the electrical machine are connected to the epicyclic gear, the greatest possible torque that can be supplied by the combustion engine and electrical machine will be limited by any one of these drive units, the greatest torque of which is lower than the greatest torque of the second drive unit, having taken the gear exchange between them into consideration. In the case in which the greatest torque of the electrical machine is lower than the greatest torque of the combustion engine, having taken the gear exchange between them into account, the electrical machine will not be able to produce a sufficiently large reactive torque to the epicyclic gear, and this leads to the combustion engine not being able to transfer its highest torque to the gearbox and onwards to the driving wheels of the vehicle. The highest torque that can be transferred to the gearbox is in this way limited by the power of the electrical machine. This is made clear also by the equation known as the “planetary equation”.

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There are disadvantages associated with using a conventional clutch that disconnects the input shaft to the gearbox from the combustion engine while gear-change processes are taking place

in the gearbox, such as the heating of the lamellae of the clutch, which results in wear to the clutch lamellae and to increased fuel consumption. Furthermore, a conventional clutch mechanism is relatively heavy and expensive. Also, it occupies a relatively large space in the vehicle.

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The document EP-B1-1126987 reveals a gearbox with double epicyclic gears. The sun gear of each epicyclic gear is connected to an electrical machine, and the ring gears of the epicyclic gears are connected to each other. The planet gear carriers of each epicyclic gear are connected to a number of gear pairs, in such a manner that an infinite number of gear steps is
10 obtained. Another document, EP-B1-1280677, reveals also how the epicyclic gears can be bridged by a gear step arranged at the output shaft of the combustion engine.

The document US-A1-20050227803 reveals a vehicle transmission with two electrical machines, each one of which is connected to a sun gear in one of two epicyclic gears. The epicyclic gears have a common planet gear carrier, which is connected to the input shaft of the
15 transmission.

The document WO2008/046185-A1 reveals a hybrid transmission with two epicyclic gears, whereby an electrical machine is connected to one of the epicyclic gears and a double clutch
20 interacts with the second epicyclic gear. The two epicyclic gears interact also with each other through a cogged wheel transmission.

SUMMARY OF THE INVENTION

25 Despite known solutions in the technical area being available, there is a need to develop further a gearbox that changes gears without interruption in torque, that demonstrates a regenerative brake arrangement, that has a compact design, that has a high reliability and high dependability, that demonstrates low weight, and that under certain operating conditions is self-sufficient with respect to the supply of electricity.

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The space available for the drive arrangement in a vehicle is often limited. If the drive arrangement comprises several components, such as a combustion engine, an electrical machine, a gearbox and an epicyclic gear, the design must be compact. If further components, such as a regenerative brake arrangement, are to be included, even stricter demands are placed

that the components that are parts of the drive arrangement have a compact design. At the same time, the components that are parts of the drive arrangement must be designed with dimensions that can absorb the necessary forces and torques.

- 5 A large number of gear steps are required in certain types of vehicle, in particular in lorries and buses. In this case, the number of components that are parts of the gearbox increases, and the gearbox also must be dimensioned such that it can absorb large forces and torques, that arise in such heavy vehicles. This results in the size and weight of the gearbox increasing.
- 10 High demands are placed also on high reliability and high dependability, for the components that are parts of the drive arrangement. Wear arises in cases in which the gearbox contains lamellar clutches, which wear influences the reliability and lifetime of the gearbox.

Kinetic energy is converted into electrical energy during regenerative braking, which electrical energy is stored in an energy store, such as accumulators. One factor that influences the lifetime of the energy store is the number of cycles that the energy store supplies current to the electrical machines and receives current from them. The greater the number of cycles, the shorter will be the lifetime of the energy store.

- 20 The purpose of the present invention is to provide a gearbox that changes gear without interruption in torque.

A further purpose of the invention is to provide a gearbox with a regenerative brake arrangement.

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A further purpose of the invention is to provide a gearbox for a vehicle, which gearbox can be connected directly to an output shaft at the gearbox.

A further purpose of the present invention is to provide a gearbox that has a compact design.

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A further purpose of the present invention is to provide a gearbox that has high reliability and high dependability.

A further purpose of the invention is to provide a gearbox for a vehicle, which gearbox demonstrates low weight.

5 A further purpose of the present invention is to provide a gearbox that is self-sufficient with respect to electricity under certain operating conditions.

10 A further purpose of the present invention is to provide a gearbox with a regenerative brake arrangement that increases the lifetime of an energy store connected to the regenerative brake arrangement.

15 A further purpose of the invention is to provide a new and advantageous computer program for the control of the gearbox.

20 A further purpose of the present invention is to provide a gearbox in a hybrid propulsion line, which gearbox can be controlled without the influence of a combustion engine.

25 These purposes are achieved with the gearbox specified in the introduction, which gearbox is characterised by the distinctive features that are specified in the characterising part of claim 1.

30 These purposes are achieved with the vehicle specified in the introduction, which vehicle is characterised by the distinctive features that are specified in the characterising part of claim 14.

35 These purposes are achieved also with the method for controlling the gearbox that is specified in the introduction, which method is characterised by the distinctive features that are specified in the characterising part of claim 15.

40 These purposes are achieved also with the computer program for controlling the gearbox that is specified in the introduction, which computer program is characterised by the distinctive features that are specified in the characterising part of claim 19.

45 These purposes are achieved also with the computer program product for controlling the gearbox that is specified in the introduction, which computer program product is characterised by the distinctive features that are specified in the characterising part of claim 20.

By providing the gearbox, which comprises two epicyclic gears connected to each other, with a gear element that is arranged at the side shaft in a manner that allows it to be disengaged, a number of gear steps are obtained, where torque from one of the epicyclic gears can be transferred to the side shaft and onwards from the side shaft to a main shaft that is connected to the other epicyclic gear, in order finally to transfer the torque to the output shaft of the gearbox.

The electrical machines that are connected to the epicyclic gears can either generate current or supply torque, or both generate current and supply torque, depending in the desired operating condition. The electrical machines can also provide each other with current in certain operating conditions.

According to one embodiment, a first planet gear carrier at the first epicyclic gear is connected to a second sun gear at the second epicyclic gear, a first sun gear at the first epicyclic gear is connected to the first main shaft and a second planet gear carrier at the second epicyclic gear is connected to the second main shaft. A transmission that changes gear without interruption in torque is in this way achieved.

According to a further embodiment of the invention, the gearbox is provided with a number of gear pairs that comprise a cogged wheel that can be mechanically locked with a side shaft. In this way a number of fixed gear steps are obtained, between which it is possible to change gears without interruption in torque. The cogged wheels that can be engaged on the side shaft mean also that a compact design with high reliability and high dependability is obtained.

With the gearbox according to the invention, conventional slip clutches between the combustion engine and the gearbox can be avoided.

According to one embodiment, a lock mechanism is arranged to connect in a fixed manner the output shaft of the combustion engine with the gearbox housing. In this way, also the first planet gear carrier will be locked fixed to the gearbox housing. By locking the output shaft of the combustion engine and the planet gear carrier to the gearbox housing by means of the lock mechanism, the gearbox, and thus also the vehicle, will become adapted for electrical operation by the electrical machines. Thus the electrical machines provide a torque to the output shaft of the gearbox.

According to one embodiment, first and second coupling units are arranged between the planet gear carrier and the sun gear of the first and second epicyclic gears, respectively. It is the task of the coupling units to lock the relevant planet gear carrier to the sun gear. When the planet gear carrier and the sun gear are connected to each other, the force from the combustion engine will pass through the planet gear carrier, the coupling unit, the sun gear and onwards to the gearbox, which results in the planet gears not absorbing any torque. This means that the dimensions of the planet gears can be adapted solely to the torque of the electrical machine instead of to the torque of the combustion engine, which in turn means that the planet gears can be designed with smaller dimensions. Thus, a drive arrangement according to the invention that has a compact design, low weight and low cost of manufacture is in this way obtained.

It is preferable that the coupling units and lock mechanisms comprise a ring-shaped sheath that is displaced axially between its engaged and disengaged positions. The sheath essentially concentrically surrounds the rotating components of the gearbox and it is displaced between the engaged and disengaged positions by means of a force element. A compact design with low weight and low cost of manufacture is in this way obtained.

The gearbox may be preferably provided with a number of gear pairs that comprise cogged wheels that can be mechanically engaged and disengaged with a side shaft. In this way a number of fixed gear steps are obtained, between which it is possible to change gears without interruption in torque. The cogged wheels that can be engaged on the side shaft mean also that a compact design with high reliability and high dependability is obtained. Alternatively, cogged wheel drives can be arranged at the gear pairs, such that they can be engaged and disengaged at at least one of the first and second main shafts.

Each one of the gear pairs has a gear exchange that is adapted to the desired driving performance of the vehicle. It is appropriate that the gear pair with the highest gear exchange, relative to the other gear pairs, is engaged when the lowest gear has been selected.

In order to disengage the sun gear and planet gear carrier at the relevant epicyclic gear, at least one of the first and second electrical machines is controlled such that torque balance is prevalent in the epicyclic gear. When ~~one~~ torque balance has been achieved, the first or the

second coupling unit is displaced such that the sun gear and the planet gear carrier are no longer mechanically connected to each other.

The term “torque balance” is here used to denote a condition in which a torque acts on a ring gear arranged at the epicyclic gear, corresponding to the product of the torque that acts on the planet gear carrier of the epicyclic gear and the gear exchange ratio of the planet gear, while at the same time a torque acts on the sun gear of the epicyclic gear, corresponding to the product of the torque that acts on the planet gear carrier and (1-the gear exchange ratio of the planet gear). In the case in which two of the component parts of the epicyclic gear, sun gear, ring gear and planet gear carrier, are connected by means of a coupling unit, this coupling unit transfers no torque between the components of the epicyclic gear when torque balance is prevalent. The coupling unit can in this way be displaced in a simple manner, and the components of the epicyclic gear disengaged.

BRIEF DESCRIPTION OF DRAWINGS

A preferred embodiments of the invention will be described as an example below with refer-
5 ence to attached drawings, of which:

Figure 1 shows schematically a vehicle in a side view with a gearbox according to the
present invention,

10 Figure 2 shows a schematic side view of the gearbox according to the present invention,

Figure 3 shows a schematic view of the gearbox according to present invention, and

Figure 4 shows a flow diagram concerning a method to control the gearbox according to
15 the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Figure 1 shows schematically a side view of a vehicle 1 that comprises a gearbox 2 according
20 to the present invention. A combustion engine 4 is connected to the gearbox 2 and the gear-
box 2 is further connected to the driving wheels 6 of the vehicle 1.

Figure 2 shows a schematic side view of the gearbox 2 according to the present invention.

The gearbox 2 comprises an input shaft 8, first and second epicyclic gears 10 and 12, first and
25 second electrical machines 14 and 16, a side shaft 18 and an output shaft 20. The first epi-
cyclic gear 10 has a first ring gear 22, to which a first rotor 24 at the first electrical machine
14 is connected. The first epicyclic gear 10 has also a first sun gear 26. The second epicyclic
gear 12 has a second ring gear 28, to which a second rotor 30 at the second electrical machine
16 is connected. The second epicyclic gear 12 has a second sun gear 32. The first and second
30 sun gears 26 and 32 are arranged coaxially, which, according to the design that is shown, re-
sults in that a first main shaft 34 arranged at the first sun gear 26 extends inside a second main
shaft 36 arranged at the second sun gear 32, which second main shaft 36 is provided with a
central bore 38. It is possible also to arrange the first main shaft 34 parallel to and at the side
of the second main shaft 36.

The first electrical machine 14 is provided with a first stator 40 that is connected to the vehicle 1, through a gear housing 42 that surrounds the gearbox 2. The second electrical machine 16 is provided with a second stator 44 that is connected to the vehicle 1, through the gear housing 42 that surrounds the gearbox 2. The first 14 and second electrical machine 16 is connected to an energy store 46, such as a battery, that drives the electrical machines 14 and 16 depending of the operating condition of the vehicle 1. In other operating conditions, the electrical machines 14 and 16 can function as generators, whereby current is supplied to the energy store 46. An electronic control unit 48 is connected to the energy store 46 and controls the supply of current to the electrical machines 14 and 16. It is preferable that the energy store 46 be connected to the electrical machines 14 and 16 through a switch 49 that is connected to the control unit 48. In certain operating conditions the electrical machines 14 and 16 can also drive each other. Electrical energy is then led from one electrical machine 14, 16 to the other electrical machine 14, 16 through the switch 49 that is connected to the electrical machines 14, 16. It is possible in this way to achieve a power balance between the electrical machines 14, 16. Another computer 53 may be connected to the control unit 48 and to the gearbox 2. By leading electrical energy from one of the electrical machines 14, 16 to the other electrical machine 14, 16 through the switch 49, electrical energy will not be led to and from the energy store 46. In this way, the conditions required for an increased lifetime of the energy store 46 are achieved. It is thus possible also to carry out gear changes and to propel the vehicle 1 without an energy store 46.

The first epicyclic gear 10 is provided with a first planet gear carrier 50, on which a first set of planet gears 52 is mounted in bearings. The second epicyclic gear 12 is provided with a second planet gear carrier 51, on which a second set of planet gears 54 is mounted in bearings. The first set of planet gears 52 interacts with the first ring gear 22 and with the first sun gear 26. The second set of planet gears 54 interacts with the second ring gear 28 and the second sun gear 32. The input shaft 8 of the gearbox 2 is connected to the first planet gear carrier 50. The first planet gear carrier 50 at the first epicyclic gear 10 is directly and fixed connected to the second sun gear 32 at the second epicyclic gear 12. The first planet gear carrier 50 and the second sun gear 32 in this way will always demonstrate the same direction of rotation and the same rate of revolution.

A first coupling unit 56 is arranged between the first sun gear 26 and the first planet gear carrier 50. By arranging the first coupling unit 56 such that the first sun gear 26 and the first planet gear carrier 50 are connected to each other and thus not able to rotate relative to each other, the first planet gear carrier 50 and the first sun gear 26 will rotate with equal rates of revolution.

A second coupling unit 58 is arranged between the second sun gear 32 and the second planet gear carrier 51. By arranging the second coupling unit 58 such that the second sun gear 32 and the second planet gear carrier 51 are connected to each other and thus not able to rotate relative to each other, the second planet gear carrier 51 and the second sun gear 32 will rotate with equal rates of revolution.

It is preferable that the first and second coupling units 56, 58 comprise first and second coupling sheaths 55 and 57 equipped with splines that can be displaced axially at a spline-equipped section with the first and second planet gear carrier 50 and 51 and at a spline-equipped section with the relevant sun gear 26 and 32. By displacing the relevant coupling sheath 55, 57 such that the spline-equipped sections are connected through the relevant coupling sheath 55, 57, the first planet gear carrier 50 and the first sun gear 26, and the second planet gear carrier 51 and the second sun gear 32, will become mutually locked to each other, and will not be able to rotate relative to each other.

The first and the second coupling units 56, 58 according to the design shown in Figure 2 are arranged between the first sun gear 26 and the first planet gear carrier 50 and between the second sun gear 32 and the second planet gear carrier 51, respectively. It is, however, possible to arrange a further or an alternative coupling unit (not shown in the drawings) between the first ring gear 22 and the first planet gear carrier 50, and also to arrange a further or alternative coupling unit (not shown in the drawings) between the second ring gear 28 and the second planet gear carrier 51.

A third coupling unit 59 is arranged in this embodiment between the first ring gear 22 and the gear housing 42. By arranging the third coupling unit 59 such that the first ring gear 22 and the gear housing 42 are connected to each other and thus not able to rotate relative to each other, a gearing down of torque will take place, i.e. a gearing up of the rate of revolution from the planet gear carrier 50 to the first sun gear 26 will take place.

A fourth coupling unit 61 is arranged in this embodiment between the second ring gear 28 and the gear housing 42. By arranging the fourth coupling unit 61 such that the second ring gear 28 and the gear housing 42 are connected to each other and thus not able to rotate relative to each other, a gearing down of torque will take place, i.e. a gearing up of the rate of revolution from the planet gear carrier 50 to the second sun gear 32 will take place.

It is preferable that the third and fourth coupling units 59, 61 comprise a third and fourth coupling sheath 65 and 67 equipped with splines that can be displaced axially at a spline-equipped section with the first and second ring gears 22 and 28 and at a spline-equipped section with the gear housing 42. By displacing the relevant coupling sheath 65, 67 such that the spline-equipped sections are connected through the relevant coupling sheath 65, 67, the first ring gear 22 and the gear housing 42, and the second ring gear 28 and the gear housing 42, will become mutually locked to each other, and will not be able to rotate relative to each other.

A transmission arrangement 19 is connected to the first and second main shaft 34, 36, which transmission arrangement comprises a first gear pair 60 that is arranged between the first epicyclic gear 10 and the output shaft 20. The first gear pair 60 comprises a first cogged wheel drive 62 and a first cogged wheel 64, which interact with each other. A second gear pair 66 is arranged between the second epicyclic gear 12 and the output shaft 20. The second gear pair 66 comprises a second cogged wheel drive 68 and a second cogged wheel 70, which interact with each other. A third gear pair 72 is arranged between the first epicyclic gear 10 and the output shaft 20. The third gear pair 72 comprises a third cogged wheel drive 74 and a third cogged wheel 76, which interact with each other. A fourth gear pair 78 is arranged between the second epicyclic gear 12 and the output shaft 20. The fourth gear pair 78 comprises a fourth cogged wheel drive 80 and a fourth cogged wheel 82, which interact with each other.

The first and third cogged wheel drives 62 and 74 are arranged at the first main shaft 34. The first and third cogged wheel drives 62 and 74 are fixed connected to the first main shaft 34, such that they cannot rotate relative to the first main shaft 34. The second and fourth cogged wheel drives 68 and 80 are arranged at the second main shaft 36. The second and fourth cogged wheel drive 68 and 80 are fixed connected to the second main shaft 36, such that they cannot rotate relative to the second main shaft 36.

The side shaft 18 extends essentially parallel to the first and second main shafts 34 and 36.

The first, second, third and fourth cogged wheels 64, 70, 76 and 82 are arranged in bearings at the side shaft 18. The first cogged wheel drive 62 interacts with the first cogged wheel 64, the
5 second cogged wheel drive 68 interacts with the second cogged wheel 70, the third cogged wheel drive 74 interacts with the third cogged wheel 76 and the fourth cogged wheel drive 80 interacts with the fourth cogged wheel 82.

The first, second, third and fourth cogged wheels 64, 70, 76 and 82 can be individually locked
10 engaged and disengaged at the side shaft 18 with the aid of first, second, third and fourth coupling elements 84, 86, 88 and 90. The coupling elements 84, 86, 88 and 90 are preferably constituted by sections equipped with splines designed at the cogged wheels 64, 70, 76 and 82 and the side shaft 18 that interact with the fifth and sixth coupling sheaths 83, 85, which interact mechanically with the sections equipped with splines at the first to fourth cogged wheels
15 64, 70, 76 and 82, respectively, and the side shaft 18. It is preferable that the first and third coupling elements 84, 88 are provided with a common coupling sheath 83, and it is preferable that the second and fourth coupling elements 86, 90 are provided with a common coupling sheath 85. When in the disengaged condition, a relative rotation can arise between the cogged wheels 64, 70, 76 and 82 and the side shaft 18. The coupling elements 84, 86, 88 and 90 may
20 be constituted also by friction couplings. Also a fifth cogged wheel 92 is arranged at the side shaft 18 that interacts with a sixth cogged wheel 94, which is arranged at the output shaft 20 of the gearbox 2.

The side shaft 18 is arranged between the relevant first or second epicyclic gear 10, 12 and the
25 output shaft 20, such that side shaft 18 is connected to the output shaft 20 through a final gear or a fifth gear pair 21, that comprises the fifth and sixth cogged wheels 92, 94. The fifth cogged wheel is arranged at the side shaft 18 by means of a fifth coupling element 93, in a manner that allows it to be engaged and disengaged.

30 By disengaging the fifth cogged wheel 92 that is arranged at the side shaft 18 in a manner that allows it to be disengaged, it will become possible to transfer torque from the second epicyclic gear 12 to the side shaft 18 through the second gear pair 66 and to transfer torque onwards from the side shaft 18 to the output shaft 20 through the first gear pair 60. In this way, a number of gear steps are obtained, where torque from one of the epicyclic gears 10, 12 can be

transferred to the side shaft 18 and onwards from the side shaft 18 to a main shaft 34, 36 that is connected to the other epicyclic gear 10, 12, in order finally to transfer torque to the output shaft 20 of the gearbox. This requires, however, that a coupling mechanism 96 arranged between the first main shaft 34 and the output shaft 20 is engaged, which will be described in more detail below.

The fifth cogged wheel 92 can be locked and freed at the side shaft 18 with the aid of a fifth coupling element 93. It is preferable that the coupling element 93 be constituted by sections that are equipped with splines designed at the fifth cogged wheel 92 and the side shaft 18, which sections interact with a ninth coupling sheath 87 that interacts mechanically with the sections that are equipped with splines at the fifth cogged wheel 92 and the side shaft 18. When in the disengaged condition, a relative rotation can arise between the fifth cogged wheel 92 and the side shaft 18. The fifth coupling element 93 may be constituted also by friction couplings.

During a number of gear change operations when the ring gears of the epicyclic gears 10, 12 are locked fixed at the gear housing 42 with the aid of the third and fourth coupling units 59, 61 the torque will be geared down after the first epicyclic gear 10 and geared up after the second epicyclic gear 12. When the transfer of torque over the first main shaft 34 through the side shaft 18 becomes less after the first epicyclic gear 10, shafts, cogged drives and cogged wheels that are connected to it can be given smaller dimensions, which will make the gearbox 2 more compact. Also a large number of gear steps can be obtained without it being necessary to arrange a number of further gear pairs in the gearbox. In this way, also the weight and cost of the gearbox 2 are reduced. The fifth and sixth cogged wheels 92 and 94 will function as a fifth gear pair 21 that transfers torque to the output shaft 20 of the gearbox 2.

The transfer of torque from the input shaft 8 of the gearbox 2 to the output shaft 20 of the gearbox 2 takes place through either the first 10 or the second epicyclic gear 12 and the side shaft 18. The transfer of torque may take place also directly through the first epicyclic gear 10, the first sun gear 26 of which is connected through the first main shaft 34 to the output shaft 20 of the gearbox 2 through a coupling mechanism 96. It is preferable that the coupling mechanism 96 comprise a seventh coupling sheath 100 equipped with splines, which coupling sheath can be axially displaced at the first main shaft 34 and the sections of the output axle 20 that are equipped with splines. By displacing the seventh coupling sheath 100 such that the

sections that are equipped with splines are connected through the seventh coupling sheath 100, the first main shaft 34 will become fixed locked with the output shaft 20, and they will thus demonstrate on rotation the same rate of revolution. By disengaging the fifth cogged wheel 92 of the fifth gear pair 21 from the side shaft 18, torque from the second epicyclic gear 12 can be transferred to the side shaft 18 and onwards from the side shaft 18 to the main shaft 34, which is connected to the first epicyclic gear 10, in order finally to transfer torque to the output shaft 20 of the gearbox 2 through the coupling mechanism 96.

During operation, the gearbox 2 may work in certain operating conditions such that one of the sun gears 26 or 32 is locked against the first or second planet gear carrier 50 or 51 with the aid of the first or second coupling unit 56 or 58. The first or second main shaft 34 or 36 will then be given the same rate of revolution as the input shaft 8 of the gearbox 2, depending on which sun gear 26 or 32 that has been locked fixed at the relevant planet gear carrier 50 or 51. One or both of the electrical machines 14 and 16 may function as a generator in order to generate electrical energy to the energy store 46. Alternatively, the electrical machine 14 or 16 may provide an increase in torque in order in this way to increase the torque at the output shaft 20. The electrical machines 14 and 16 will, under certain operating conditions, provide each other with electrical energy, independently of the energy store 46.

Also the gearbox 2 may, in certain operating conditions, function such that one of the rotors 24 and 30 at the electrical machines 14 and 16 is locked fixed with the gear housing 42 through the ring gears 22 and 28, while the second electrical machine 14 and 16 functions as a generator in order to generate electrical energy to the energy store 46, which will be explained in more detail below. The electrical machine 14 or 16 whose rotor 24 or 30 is locked fixed with the gear housing 42 absorbs a reactive torque from the ring gear 22 or 28, before the locking is carried out with the aid of the third or fourth coupling unit 59 or 61. Instead of functioning as a generator, the electrical machine 14 or 16 may provide an increase in torque in order in this way to increase the torque at the output shaft 20.

It is possible also that both the first and second electrical machines 14 and 16 generate current to the energy store 46 at the same time. The driver releases the accelerator pedal (not shown in the drawings) of the vehicle 1 during engine braking. The output shaft 20 of the gearbox 2 then drives either one or both of the electrical machines 14 and 16, while the combustion engine 4 and the electrical machines 14 and 16 engine provide at the same time en-

gine braking. The electrical machines 14 and 16 generate in this case electrical energy that is stored in the energy store 46 in the vehicle 1. This operating condition is known as “regenerative braking”. In order to make a more powerful braking effect possible, the output shaft 97 of the combustion engine 4 may be fixed locked and in this way prevented from rotating. Thus, only one or both of the electrical machines 14 and 16 will function as a brake and generate electrical energy, which is stored in the energy store 46. The locking of the output shaft 97 of the combustion engine 4 may be carried out also when the vehicle is to be accelerated by only one or both of the electrical machines 14 and 16. If the torque of one or both of the electrical machines 14 and 16 exceeds the torque of the combustion engine 4, taking the gear exchange between them into consideration, the combustion engine 4 will not be able to withstand the large torque that the electrical machines 14 and 16 produce, for which reason it will be necessary to lock fixed the output shaft 97 of the combustion engine 4. The locking of the output shaft 97 of the combustion engine 4 is preferably carried out with a lock arrangement 102 that is arranged between the first planet gear carrier 50 and the gear housing 42. By locking the first planet gear carrier 50 and the gear housing 42, also the output shaft 97 of the combustion engine 4 will be locked, since the output shaft 97 of the combustion engine 4 is connected to the first planet gear carrier 50 through the input shaft 8 of the gearbox. It is preferable that the lock arrangement 102 comprise an eighth coupling sheath 104 equipped with splines that can be displaced axially at a spline-equipped section with the first planet gear carrier 50 and at a spline-equipped section with the gear housing. By displacing the eighth coupling sheath 104 such that the sections that are equipped with splines are connected through the coupling sheath 104, the first planet gear carrier 50 and thus also the output shaft 97 of the combustion engine 4 will be prevented from rotating.

The control unit 48 is connected to the electrical machines 14 and 16 and is adapted to control the electrical machines 14 and 16 such that under certain suitable operating conditions they use stored electrical energy in order to provide driving force to the output shaft 20 of the gearbox 2, and such that under other operating conditions they use the kinetic energy of the output shaft 20 of the gearbox 2 in order to produce and store electrical energy. The control unit 48 thus detects at least one of the rate of revolution and the torque at the output shaft 97 of the combustion engine 4 through sensors 98 arranged at the electrical machines 14 and 16 and at the output shaft 20 of the gearbox 2 in order in this way to collect information and to control the electrical machines 14 and 16 such that they function as electric motors or generators. The control unit 48 may be a computer with appropriate software for this purpose. The

control unit 48 controls also the flow of electrical energy between the energy store 46 and the relevant stator 40 and 44 at the electrical machines 14 and 16. In conditions in which the electrical machines 14 and 16 function as motors, stored electrical energy is supplied from the energy store 46 to the relevant stator 40 and 44. In conditions in which the electrical machines
5 14 and 16 function as generators, electrical energy is supplied from the relevant stator 40 and 44 to the energy store 46. The electrical machines 14 and 16 can, however, as has been mentioned above, provide each other with electrical energy under certain operating conditions, independently of the energy store 46.

10 The first, second, third and fourth coupling units 56, 58, 59 and 61, the first, second, third, fourth and fifth coupling elements 84, 86, 88, 90 and 93, the coupling mechanism 96 between the first main shaft 34 and the output shaft 20, and the lock arrangement 102 between the first planet gear carrier 50 and the gear housing 42 are connected to the control unit 48 through the relevant coupling sheaths. It is preferable that these components are activated and deactivated
15 by electrical signals from the control unit 48. It is preferable that the coupling sheaths are displaced by force providers, not shown in the drawings, such as hydraulically or pneumatically powered cylinders. It is possible to displace the coupling sheaths also by electrically powered force providers.

20 According to the embodiment in Figure 2, four cogged wheel drives 62, 68, 74 and 80 and four cogged wheels 64, 70, 76 and 82 are shown together with two epicyclic gears 10 and 12 with their associated electrical machines 14 and 16. It is, however, possible to design the gearbox 2 with a greater or lesser number of cogged wheel drives and cogged wheels and with a greater number of epicyclic gears with their associated electrical machines.

25 According to Figure 3, there is illustrated a hybrid propulsion line 3 according to Figure 2 in a simplified schematic view in which certain components have been omitted for reasons of clarity. Figure 3 shows a gear pair G1 connected to the first main shaft 34 and thus also to the first epicyclic gear 10, and a gear pair G2 connected to the second main shaft 36 and thus also
30 to the second epicyclic gear 12. These gear pairs G1, G2 are connected also to the output shaft 20 through the side shaft 18. The gear pair G1 that is connected to the first main shaft 34 may be constituted by, for example, the first gear pair 60 or the third gear pair 72 as described in Figures 2 and 3, and it may comprise also further gear pairs. The gear pair G2 that is connected to the second main shaft 36 may be constituted by, for example, the second gear pair

66 or the fourth gear pair 78 as described in Figures 2 and 3, and it may comprise also further gear pairs. Furthermore, the fifth gear pair G3, 21 that is connected to the output shaft 20 and the side shaft 18 and that is described also in Figures 2 and 3 is shown. G3 may, however, be constituted by further gear pairs. When changing gear, a suitable gear pair from the relevant group G1, G2, G3 is selected.

The, at least one, gear pair G1, 60, 72 that is connected to the first epicyclic gear 10 comprises at least one cogged wheel drive 62, 74 and cogged wheel 64, 76 arranged to interact with each other, which cogged wheel drive 62, 74 may be arranged such that it can be engaged and disengaged at the first main shaft 34 arranged with the first epicyclic gear 10. The, at least one, cogged wheel 64, 76 may be arranged such that it can be engaged and disengaged at the side shaft 18.

The, at least one, gear pair G2, 66, 78 that is connected to the second epicyclic gear 12 comprises at least one cogged wheel drive 68, 80 and cogged wheel 70, 82 arranged to interact with each other, which cogged wheel drive 68, 80 may be arranged such that it can be engaged and disengaged at the second main shaft 36 arranged with the second epicyclic gear 12. The, at least one, cogged wheel 70, 82 may be arranged such that it can be engaged and disengaged at the side shaft 18.

Gearing up from the first to the highest gear when the gearbox 2 is arranged in a vehicle 1 will be described below. The input shaft 8 of the gearbox 2 is connected to the output shaft 97 of the combustion engine 4 of the vehicle 1. The output shaft 20 of the gearbox 2 is connected to a drive shaft 99 at the vehicle 1. During idling of the combustion engine 4 and when the vehicle 1 is stationary, the input shaft 8 of the gearbox 2 rotates while the output shaft 20 of the gearbox 2 is at the same time stationary. The lock arrangement 102 is deactivated such that the output shaft 97 of the combustion engine 4 can rotate freely. Since the input shaft 8 of the gearbox 2 rotates, also the first planet gear carrier 50 will rotate, which leads to the first set of planet gears 52 rotating. Since the first planet gear carrier 50 is connected to the second sun gear 32, the second sun gear 32 and thus also the second set of planet gears 54 will rotate. By not supplying current and not withdrawing current from the first and second electrical machines 14 and 16, the first and second ring gears 22 and 28, which are connected to the first and second rotors 24 and 30, respectively, at the relevant electrical machine 14 and 16, will rotate freely, whereby no torque is absorbed by the ring gears 22 and 28. The first, second,

third and fourth coupling units 56, 58, 59 and 61 are disengaged and thus are not engaged. Thus, no torque will be transferred from the combustion engine 4 to the sun gears 26 and 32 of the epicyclic gears 10 and 12. The coupling mechanism 96 between the first main shaft 34 and the output shaft 20 is disengaged, such that the first main shaft 34 and the output shaft 20 can rotate freely relative to each other. Since the sun gears 26 and 32 and the output shaft 20 of the gearbox 2 are in this phase stationary, also the side shaft 18 is stationary. In a first step the fourth cogged wheel 82 and the third cogged wheel 76 are connected to the side shaft 18 with the aid of the fourth and third coupling elements 90 and 88. The first cogged wheel 64 and the second cogged wheel 70 are disengaged from the side shaft 18. In this way, the first cogged wheel 64 and the second cogged wheel 70 are allowed to rotate freely relative to the side shaft 18. The fifth cogged wheel 92 at the fifth gear pair 21 is locked fixed at the side shaft 18 with the aid of the fifth coupling element 93.

In order to start rotation of the output shaft 20 of the gearbox 2 with the purpose of driving the vehicle 1, the fourth cogged wheel drive 80 and the fourth cogged wheel 82 at the side shaft 18 are to be caused to rotate. This is achieved through the second planet gear carrier 51 being caused to rotate. When the second planet gear carrier rotates, also the second main shaft 36 will rotate and thus also the fourth cogged wheel drive 80, which is arranged at the second main shaft 36, will rotate. The second planet gear carrier 51 is caused to rotate through the second ring gear 28 being controlled with the second electrical machine 16. By activating the second electrical machine 16 and controlling the combustion engine 4 to a suitable rate of revolution, the vehicle 1 will start to be displaced through the second main shaft 36 starting to rotate. When the second planet gear carrier 51 and the second sun gear 32 achieve the same rate of revolution, the second sun gear 32 is locked fixed with the second planet gear carrier 51 with the aid of the second coupling unit 58. As has been mentioned above, the second coupling unit 58 is preferably so designed that the second sun gear 32 and the second planet gear carrier 51 interact mechanically with each other. Alternatively, the second coupling unit 58 may be designed as a glide brake or a lamellar clutch that connects in a gentle manner the second sun gear 32 to the second planet gear carrier 51. When the second sun gear 32 is connected to the second planet gear carrier 51, the second sun gear 32 will rotate at the same rate of revolution as the output shaft 97 of the combustion engine 4. In this way, the torque produced by the combustion engine 4 will be transferred to the output shaft 20 of the gearbox 2 through the fourth cogged wheel drive 80, the fourth cogged wheel 82 at the side shaft 18, the fifth cogged wheel 92 at the side shaft 18 and the sixth cogged wheel 94 at the output shaft 20

of the gearbox 2. Thus the vehicle 1 will start to be displaced and driven forwards by the first gear.

Each one of the first, second, third and fourth gear pairs 60, 66, 72, 78 has a gear exchange
5 that is adapted to the desired driving performance of the vehicle 1. According to the embodi-
ment shown in Figure 2, the fourth gear pair 78 has the highest gear exchange compared with
the first, second and third gear pairs 60, 66, 72, which means that the fourth gear pair 78 is
connected when the lowest gear has been selected. The second gear pair 66 transfers, just as
10 the fourth gear pair 78 does, torque between the second main shaft 36 and the side shaft 18,
and it would be possible instead to design this with the highest gear exchange compared with
the other gear pairs 60, 72, 78, for which reason the second gear pair 66 in such a design
would be connected when the lowest gear has been selected.

When the side shaft 18 is caused to rotate by the fourth cogged wheel 82 at the side shaft 18,
15 also the third cogged wheel 76 at the side shaft 18 will rotate. In this way, the side shaft 18
drives the third cogged wheel 76, which in turn drives the third cogged wheel drive 74 at the
first main shaft 34. When the first main shaft 34 rotates, also the first sun gear 26 will rotate,
which in this way, depending on the rate of revolution of the output shaft 97 of the combus-
tion engine 4 and thus also the rate of revolution of the first planet gear carrier 50, will cause
20 the first ring gear 22 and the first rotor 24 at the first electrical machine 14 to rotate. In this
case, it is possible to allow the first electrical machine 14 to function as a generator in order to
supply current to at least one of the energy store 46 and the second electrical machine 16. It is
possible also that the second electrical machine 16 is driven as a generator. Alternatively, the
first electrical machine 14 can provide additional torque through the control unit 48 control-
25 ling the first electrical machine 14 to provide propulsive torque.

In order to change gear from the first gear to the second gear, the lock between the second sun
gear 32 and the second planet gear carrier 51 must be disengaged, which is achieved through
at least one of the first and the second electrical machines 14, 16 being controlled such that
30 torque balance is prevalent in the second epicyclic gear 12. After this, which the second cou-
pling unit 58 is controlled such that it releases the second sun gear 32 and the second planet
gear carrier 51 from each other. The second planet gear carrier 51 and the second main shaft
36 can rotate freely, which leads to the second sun gear 32, the second planet gear carrier 51
and the second main shaft 36 no longer driving the fourth cogged wheel drive 80, which is

arranged at the second main shaft 36. This requires that the second electrical machine 16 is not driving the second ring gear 28. The second gear is selected through the control unit 48 controlling the first electrical machine 14 such that a synchronous rate of revolution arises between the first planet gear carrier 50 and the first sun gear 26, in order to achieve a locking
5 between the first planet gear carrier 50 and the first sun gear 26. This is achieved through the first coupling unit 56 being controlled such that the first planet gear carrier 50 and the first sun gear 26 are mechanically connected to each other. Alternatively, the first coupling unit 56 may be designed as a glide brake or a lamellar clutch that connects in a gentle manner the first sun gear 26 and the first planet gear carrier 50. By synchronising the control of the combustion engine 4 and of the first and second electrical machines 14 and 16, it is possible to carry
10 out a soft and interruption-free transition from the first gear to the second gear.

The first main shaft 34 is now rotating and is being driven by the output shaft 97 of the combustion engine 4, and the first main shaft 34 is now driving the third cogged wheel drive 74.
15 The first planet gear carrier 50 is now driving the third cogged wheel drive 74 through the first sun gear 26 and the first main shaft 34. Since the third cogged wheel 76 interacts with the third cogged wheel drive 74 and is fixed connect to the side shaft 18, the third cogged wheel 76 will drive the side shaft 18, which in turn drives the fifth cogged wheel 92 at the side shaft 18. The fifth cogged wheel 92 in turn drives the output shaft 20 of the gearbox 2 through the
20 sixth cogged wheel 94, which is arranged at the output shaft 20 of the gearbox 2. The vehicle 1 is now being propelled in second gear.

When the side shaft 18 is caused to rotate by the third cogged wheel 76, also the fourth cogged wheel 82 will rotate. In this way, the side shaft 18 drives the fourth cogged wheel 82,
25 which in turn drives the fourth cogged wheel drive 80 at the second main shaft 36. When the second main shaft 36 rotates, also the second planet gear carrier 51 will rotate, which in this way, depending on the rate of revolution of the output shaft 97 of the combustion engine 4 and thus also the rate of revolution of the first planet gear carrier 50, will cause the second ring gear 28 and the second rotor 30 at the second electrical machine 16 to rotate. In this case,
30 it is possible to allow the second electrical machine 16 to function as a generator in order to supply current to at least one of the energy store 46 and the first electrical machine 14. Also the second electrical machine 16 can provide additional torque through the control unit 48 controlling the second electrical machine 16 to provide propulsive torque.

In order to change gear from the second gear to the third gear, the fourth cogged wheel 82 at the side shaft 18 must be disengaged from the side shaft 18 with the fourth coupling element 90, such that the fourth cogged wheel 82 can rotate freely relative to the side shaft 18. The side shaft 18 is subsequently connected to the second cogged wheel 70 at the side shaft 18 through the second coupling element 86. In order to achieve connection of the side shaft 18 and the second cogged wheel 70 at the side shaft 18, preferably the second electrical machine 16 is controlled such that a synchronous rate of revolution arises between the side shaft 18 and the second cogged wheel 70 at the side shaft 18. A synchronous rate of revolution can be determined through the rate of revolution of the second rotor 30 at the second electrical machine 16 being measured and through the rate of revolution of the output shaft 20 being measured. In this way, the rate of revolution of the second main shaft 36 and the rate of revolution of the side shaft 18 can be determined through the given gear exchange ratio. The rates of revolution of the relevant shafts 18 and 36 are controlled, and when a synchronous rate of revolution has arisen between the side shaft 18 and the second cogged wheel 70, the side shaft 18 and the second cogged wheel 70 are connected with the aid of the second coupling element 86.

In order to change gear from the second gear to the third gear, the lock between the first sun gear 26 and the first planet gear carrier 50 must be disengaged, which is achieved through the first and the second electrical machines 14, 16 being controlled such that torque balance is prevalent in the first epicyclic gear 10, after which the first coupling unit 56 is controlled such that it releases the first sun gear 26 and the first planet gear carrier 50 from each other. The combustion engine 4 is subsequently controlled such that a synchronous rate of revolution arises between the second sun gear 32 and the second planet gear carrier 51, such that the second coupling unit 58 can be engaged, in order in this way to connect the second sun gear 32 and the second planet gear carrier 51 by the coupling sheath 57. By synchronising the control of the combustion engine 4 and of the first and second electrical machines 14 and 16, it is possible to carry out a soft and interruption-free transition from the second gear to the third gear.

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The third cogged wheel 76 is disengaged through the first electrical machine 14 being controlled such that a condition that is free of torque arises between the side shaft 18 and the third cogged wheel 76. When a condition that is free of torque arises, the third cogged wheel 76 is disengaged from the side shaft 18 through the third coupling element 88 being controlled such

that is disengages the third cogged wheel 76 from the side shaft 18. The first electrical machine 14 is subsequently controlled such that a synchronous rate of revolution arises between the side shaft 18 and the first cogged wheel 64. When a synchronous rate of revolution has arisen, the first cogged wheel 64 is connected to the side shaft 18 through the first coupling element 84 being controlled such that it connects the first cogged wheel 64 to the side shaft 18. A synchronous rate of revolution can be determined through the rate of revolution of the first rotor 24 at the first electrical machine 14 being measured and through the rate of revolution of the output shaft 20 being measured, after which the rates of revolution of the shafts 18, 34 are controlled such that a synchronous rate of revolution arises. In this way, the rate of revolution of the first main shaft 34 and the rate of revolution of the side shaft 18 can be determined through the given gear exchange ratio.

The second main shaft 36 is now rotating with the same rate of revolution as the output shaft 97 of the combustion engine 4, and the second main shaft 36 is now driving the second cogged wheel drive 68 through the second main shaft 36. Since the second cogged wheel 70 is in interaction with the second cogged wheel drive 68 and is fixed connected to the side shaft 18, the second cogged wheel 70 will drive the side shaft 18, which in turn drives the fifth cogged wheel 92 at the side shaft 18. The fifth cogged wheel 92 in turn drives the output shaft 20 of the gearbox 2 through the sixth cogged wheel 94, which is arranged at the output shaft 20 of the gearbox 2. The vehicle 1 is now being propelled in third gear.

When the side shaft 18 is caused to rotate by the second cogged wheel 70 at the side shaft 18, also the first cogged wheel 64 at the side shaft 18 will rotate. The side shaft 18 in this way drives the first cogged wheel 64, which in turn drives the first cogged wheel drive 62 at the first main shaft 34. When the first main shaft 34 rotates, also the first sun gear 26 will rotate, which in this way, depending on the rate of revolution of the output shaft 97 of the combustion engine 4 and thus also the rate of revolution of the first planet gear carrier 50, will cause the first ring gear 22 and the first rotor 24 at the first electrical machine 14 to rotate. In this case, it is possible to allow the first electrical machine 14 to function as a generator in order to supply current to at least one of the energy store 46 and the second electrical machine 16. Alternatively, the first electrical machine 14 can provide additional torque through the control unit 48 controlling the first electrical machine 14 to provide propulsive torque.

In order to change gear from the third gear to the fourth gear, the lock between the second sun gear 32 and the second planet gear carrier 51 must be disengaged, which is achieved through the first and the second electrical machines 14, 16 being controlled such that torque balance is prevalent in the second epicyclic gear 12, after which the second coupling unit 58 is controlled such that it releases the second sun gear 32 and the second planet gear carrier 51 from each other. The first ring gear 22 is subsequently braked, and when the first ring gear 22 is stationary the third coupling unit 59 is controlled such that the first ring gear 22 is connected to and united with the gear housing 42. By synchronising the control of the combustion engine 4 and of the first and second electrical machines 14 and 16, it is possible to carry out a soft and interruption-free transition from the third gear to the fourth gear.

The first main shaft 34 is now being driven by the output shaft 97 of the combustion engine 4, and the first main shaft 34 is now driving the first cogged wheel drive 62. Since the first cogged wheel 64 interacts with the first cogged wheel drive 62 and is fixed connected to the side shaft 18, the first cogged wheel 64 will drive the side shaft 18, which in turn drives the fifth cogged wheel 92 at the side shaft 18. The fifth cogged wheel 92 in turn drives the output shaft 20 of the gearbox 2 through the sixth cogged wheel 94, which is arranged at the output shaft 20 of the gearbox 2. The vehicle 1 is now being propelled in fourth gear.

When the side shaft 18 is caused to rotate by the first cogged wheel 64, also the second cogged wheel 70 at the side shaft 18 will rotate. In this way, the side shaft 18 drives the second cogged wheel 70, which in turn drives the second cogged wheel drive 68 at the second main shaft 36. When the second main shaft 36 rotates, also the second planet gear carrier 51 will rotate, which in this way, depending on the rate of revolution of the output shaft 97 of the combustion engine 4 and thus also the rate of revolution of the first planet gear carrier 50, will cause the second sun gear 32 and the second rotor 30 at the second electrical machine 16 to rotate. In this case, it is possible to allow the second electrical machine 16 to function as a generator in order to supply current to at least one of the energy store 46 and the first electrical machine 14. Alternatively, the second electrical machine 16 can provide additional torque through the control unit 48 controlling the second electrical machine 16 to provide propulsive torque.

In order to change gear from the fourth gear to the fifth gear, the first electrical machine 14 is controlled such that torque balance arises between the first ring gear 22 and the gear housing

42. When torque balance has arisen between the first ring gear 22 and the gear housing 42, the third coupling unit 59 is controlled such that the first ring gear 22 is disengaged from the gear housing 42. Torque balance comprises not only a torque-free condition, but also a counteracting torque such that the fourth coupling unit 61 is to be placed into a condition in which it does not transfer torque between the second ring gear 28 and the gear housing 42. The first electrical machine 14 is subsequently controlled such that a torque-free condition arises between the side shaft 18 and the first cogged wheel 64. When a torque-free condition has arisen between the side shaft 18 and the first cogged wheel 64, the first coupling element 84 is controlled such that the first cogged wheel 64 is disengaged from the side shaft 18. In this way, the fourth gear has been unselected. In order to select the fifth gear, the first electrical machine 14 is controlled such that a synchronous rate of revolution arises between the first main shaft 34 and the output shaft 20. When a synchronous rate of revolution has arisen between the first main shaft 34 and the output shaft 20, the coupling mechanism 96 is controlled such that the first main shaft 34 and the output shaft 20 are connected to and united with each other. Furthermore, the first electrical machine 14 is controlled such that a torque-free condition arises between the side shaft 18 and the fifth cogged wheel 92 at the fifth gear pair 21. When a torque-free condition has arisen between the side shaft 18 and the fifth cogged wheel 92, the fifth coupling element 93 is controlled such that the fifth cogged wheel 92 is disengaged from the side shaft 18. The first electrical machine 14 is subsequently controlled such that a synchronous rate of revolution arises between the side shaft 18 and the first cogged wheel 64. When a synchronous rate of revolution has arisen between the side shaft 18 and the first cogged wheel 64, the coupling element 84 is controlled such that the first cogged wheel 64 is connected to and united with the side shaft 18. Finally, the combustion engine 4 is controlled such that the second ring gear 28 is stationary relative to the gear housing 42. When the second ring gear 28 is stationary, the fourth coupling unit 61 is controlled such that the second ring gear 28 is connected to and locked fixed to the gear housing 42. The vehicle 1 is now being propelled in the fifth gear.

When the fifth gear has been selected, the torque from the combustion engine 4 will pass the first and second planet gear carriers 50, 51 and will be transferred from the second main shaft 36 through the second gear pair 66 to the side shaft 18 and onwards through the first gear pair 60 to the first main shaft 34 in order subsequently to be transferred through the coupling mechanism 96 to the output shaft 20.

In order to change gear from the fifth gear to the sixth gear, the second electrical machine 16 is controlled such that torque balance arises between the second ring gear 28 and the gear housing 42. When torque balance has arisen between the second ring gear 28 and the gear housing 42 the fourth coupling unit 61 is controlled such that the second ring gear 28 is disengaged from the gear housing 42. The combustion engine 4 is subsequently controlled such that a synchronous rate of revolution arises between the first sun gear 26 and the first planet gear carrier 50. When a synchronous rate of revolution has arisen between the first sun gear 26 and the first planet gear carrier 50, the first coupling unit 56 is controlled such that the first sun gear 26 is connect to and united with the first planet gear carrier 50. Furthermore, the second electrical machine 16 is controlled such that a torque-free condition arises between the side shaft 18 and the first cogged wheel 64. When a torque-free condition has arisen between the side shaft 18 and the first cogged wheel 64, the coupling element 84 is controlled such that the first cogged wheel 64 is disengaged from the side shaft 18. Finally, the second electrical machine 16 is controlled such that a synchronous rate of revolution arises between the side shaft 18 and the third cogged wheel 76. When a synchronous rate of revolution has arisen between the side shaft 18 and the third cogged wheel 76, the coupling element 88 is controlled such that the third cogged wheel 76 is connected to and locked fixed with the side shaft 18. The vehicle 1 is now being propelled in the sixth gear.

When the sixth gear has been selected, the torque from the combustion engine 4 will be transferred from the first planet gear carrier 50 to the first sun gear 26 and onwards to the first main shaft 34 in order subsequently to be transferred through the coupling mechanism 96 to the output shaft 20.

In order to change gears from the sixth gear to the seventh gear the first and second electrical machines 14, 16 are controlled such that torque balance is prevalent in the first epicyclic gear 10. When torque balance is prevalent in the first epicyclic gear 10, the first coupling unit 56 is controlled such that the first sun gear 26 is disengaged from the first planet gear carrier 50. The combustion engine 4 is subsequently controlled such that a synchronous rate of revolution arises between the second sun gear 32 and the second planet gear carrier 51. When a synchronous rate of revolution has arisen between the second sun gear 32 and the second planet gear carrier 51, the second coupling unit 58 is controlled such that the second sun gear 32 is connected to and united with the second planet gear carrier 51. The vehicle 1 is now being propelled in the seventh gear.

When the seventh gear has been selected, torque from the combustion engine 4 will pass the first planet gear carrier 50 and onwards to the second main shaft 36. Torque is subsequently transferred from the second main shaft 36 through the second gear pair 66 to the side shaft 18
5 and onwards through the third gear pair 72 to the first main shaft 34, in order subsequently to be transferred through the coupling mechanism 96 to the output shaft 20.

According to the design described above, it is stated that the gearbox 2 comprises cogged wheel drives 62, 68, 74, 80 and cogged wheels 64, 70, 76, 82 arranged at the main shafts 34,
10 36 and the side shaft 18 in order to transfer rates of revolution and torque. It is, however, possible to use another type of transmission, such as chain and belt transmissions in order to transfer rates of revolution and torque in the gearbox 2.

The transmission arrangement 19 demonstrates according to the embodiment above four gear
15 pairs 60, 66, 72, 78. The transmission arrangement 19, however, may comprise a freely chosen number of gear pairs.

As has been described above, torque is withdrawn from the gearbox 2 from the output shaft
20 20. It is possible also to withdraw torque directly from the first or the second main shaft 34, 36, or directly from the side shaft 18. Torque may be withdrawn also in parallel from two or three of the shafts 18, 34, 36 at the same time.

It is preferable that the second electrical machine 16 is driven with electricity generated from
25 the first electrical machine 14 in order to reduce with the second electrical machine 16 the reactive torque from the second epicyclic gear 12, and in order in this way to reduce the torque transferred at the second gear pair 66. The reactive torque from the first epicyclic gear 10 is increased with the first electrical machine 14, in order to increase the torque transferred at the first gear pair 60.

30 It is possible also to drive the first electrical machine 14 with electrical energy generated from the second electrical machine 16 in order to reduce with the first electrical machine 14 the reactive torque from the first epicyclic gear 10, and in order in this way to reduce the torque transferred at the first gear pair 60. The reactive torque from the first epicyclic gear 10 is in-

creased with the second electrical machine 16, in order to increase the torque transferred at the second gear pair 66.

Figure 4 shows a flow diagram concerning a method to control the gearbox 2 according to the invention. The method according to the invention is characterised by the steps:

- 5 a) to disengage a gear element 92 that is arranged at a side shaft 18 in a manner that allows it to be disengaged and that is connected through a final gear 21 with the output shaft 20;
- b) to transfer torque from the second epicyclic gear 12 to the side shaft 18 through the second gear pair 66; and
- 10 c) to transfer torque from the side shaft 18 to the output shaft 20 through the first gear pair 60.

The method comprises also the further steps:

- d) to drive the second electrical machine 16 with electricity generated from the first electrical machine 14 in order to reduce with the second electrical machine 16 the reactive torque from
- 15 the second epicyclic gear 12, and in order in this way to reduce the torque transferred at the second gear pair 66; and
- e) to increase with the first electrical machine 14 the reactive torque from the first epicyclic gear 10, in order to increase the torque transferred at the first gear pair 60.

20 The method comprises also the further steps:

- f) to disengage with a first coupling unit 56 a first sun gear 26 arranged at the first epicyclic gear 10 and a first planet gear carrier 50 from each other; and
- g) to connect with a fourth coupling unit 61 a second ring gear 28 arranged at the second epicyclic gear 12 and a gear housing 42 to each other.

25

According to a further step of the method, the reduction and the increase in reactive torque at the first and second electrical machines 14 and 16 are synchronised, such that the torque at the output shaft 20 is constant or changes in a linear manner.

- 30 Change of gear can in this way be achieved without interruption in torque through the torque at the output shaft 20 being constant or changing in a continuous manner, during, for example, acceleration or retardation of the vehicle 1.

The specified method thus comprises all steps of a change of gear corresponding to all gears described in the embodiment above.

5 According to the invention, a computer program P that is stored in at least one of the control unit 48 and the computer 53 and that may comprise routines for the control of the gearbox 2 according to the present invention is provided.

10 The computer program P may comprise routines to control the gearbox in order to disengage the fifth cogged wheel 92 that is arranged at the side shaft in a manner that allows it to be disengaged. and that is connected through a fifth gear pair 21 to the output shaft 20.

The computer program P may comprise routines to control the gearbox in order to transfer torque from the second epicyclic gear 12 to the side shaft 18 through the second gear pair 66.

The computer program P may comprise routines to control the gearbox in order to transfer torque from the side shaft 18 to the output shaft 20 through the first gear pair 60.

15 The computer program P may comprise routines to control the gearbox such that the first electrical machine 14 is driven with electrical energy generated from the second electrical machine 16 in order to reduce with the first electrical machine 14 the reactive torque from the first epicyclic gear 10, and in order in this way to reduce the torque transferred at the first gear pair 60.

20 The computer program P may comprise routines to control the gearbox such that the reactive torque from the second epicyclic gear 12 is increased with the second electrical machine 16, in order to increase the torque transferred at the second gear pair 66.

The computer program P may comprise routines to control the gearbox such that a first coupling unit 56 a first sun gear 26 arranged at the first epicyclic gear 10 and a first planet gear carrier 50 are freed from each other.

The computer program P may comprise routines to control the gearbox such that a fourth coupling unit 61 a first ring gear 28 arranged at the second epicyclic gear 12 and a gear housing 42 are connected with each other.

30 The computer program P may comprise routines to control the gearbox such that the reduction and the increase in reactive torque at the first and second electrical machines 14 and 16 are synchronised, such that the torque at the output shaft 20 is constant or changes in a linear manner.

The computer program P may be stored in an executable form or in a compressed form in at least one of a memory M and a read/write memory R. The said program code may be stored in permanent form on the said medium that can be read by a computer 53.

- 5 The invention concerns also a computer program product comprising a program code stored on a medium that can be read by a computer, in order to carry out the method steps described above, when the said computer program is run on the control unit 48 or another computer 53 connected to the control unit 48.
- 10 The specified components and distinctive features that are specified above may be combined between the different specified executions within the framework of the invention.

Claims

1. A gearbox comprising an input shaft (8) and an output shaft (20); a first epicyclic gear (10) that is connected to the input shaft (8); a second epicyclic gear (12) that is connected to the
5 first epicyclic gear (10); a first electrical machine (14) that is connected to the first epicyclic gear (10); a second electrical machine (16) that is connected to the second epicyclic gear (12); a first gear pair (60) that is arranged between the first epicyclic gear (10) and the output shaft (20); and a second gear pair (66) that is arranged between the second epicyclic gear (12) and the output shaft (20);

10 **characterised in**

that a side shaft (18) is arranged between the respective first and second epicyclic gear (10, 12) and the output shaft (20);
that the side shaft (18) is connected to the output shaft (20) through a final gear (21); and
that the final gear (21) comprises a gear element (92) that is arranged at the side shaft (18) in a
15 manner that allows it to be engaged and disengaged.

2. The gearbox according to claim 1, **characterised in** that a first main shaft (34) is connected to the first epicyclic gear (10);
that a second main shaft (36) is connected to the second epicyclic gear (12);
20 that the first gear pair (60) is arranged at the first main shaft (34) and the side shaft (18); and
that the second gear pair (66) is arranged at the second main shaft (36) and the side shaft (18).

3. The gearbox according to claim 2, **characterised in** that a first planet gear carrier (50) at the first epicyclic gear (10) is connected to a second sun gear (32) at the second epicyclic gear
25 (12);
that a first sun gear (26) at the first epicyclic gear (10) is connected to the first main shaft (34); and
that a second planet gear carrier (51) at the second epicyclic gear (12) is connected to the second main shaft (36).

30

4. The gearbox according to claim 3, **characterised in** that the input shaft (8) is connected to the first planet gear carrier (50).

5. The gearbox according to any one of claims 2-4, **characterised in** that a coupling mechanism (96) is arranged between the first main shaft (34) and the output shaft (20).

6. The gearbox according to any one of claims 2-5, **characterised in** that the first gear pair (60) comprises a first cogged wheel drive (62) and a first cogged wheel (64) that interact with each other, which first cogged wheel drive (62) is fixed arranged with the first main shaft (34) and which first cogged wheel (64) is arranged at the side shaft (18) such that it can be engaged and disengaged;
that the second gear pair (66) comprises a second cogged wheel drive (68) and a second cogged wheel (70) that interact with each other, which second cogged wheel drive (68) is fixed arranged with the second main shaft (36) and which second cogged wheel (70) is arranged at the side shaft (18) such that it can be engaged and disengaged.

7. The gearbox according to claim 6, **characterised by** a third gear pair (72) that is arranged between the first epicyclic gear (10) and the output shaft (20), which third gear pair (72) comprises a third cogged wheel drive (74) and a third cogged wheel (76) that interact with each other, which third cogged wheel drive (74) is fixed arranged with the first main shaft (34) and which third cogged wheel (76) is arranged at the side shaft (18) such that it can be engaged and disengaged;
and a fourth gear pair (78) that is arranged between the second epicyclic gear (12) and the output shaft (20); which fourth gear pair (78) comprises a fourth cogged wheel drive (80) and a fourth cogged wheel (82) that interact with each other, which fourth cogged wheel drive (80) is fixed arranged with the second main shaft (36) and which fourth cogged wheel (82) is arranged at the side shaft (18) such that it can be engaged and disengaged.

8. The gearbox according to any one of the preceding claims, **characterised in** that the gear element (92) is arranged at the side shaft (18) with a fifth coupling element (93) in a manner that allows it to be disengaged.

9. The gearbox according to any one of the preceding claims, **characterised in** that the gear element of the final gear is a fifth cogged wheel (92), that interacts with a sixth cogged wheel (94), that is fixed arranged at the output shaft (20).

10. The gearbox according to claims 6 and 7, **characterised in** that the first, second, third and fourth clogged wheels (64, 70, 76, 82) are arranged at the side shaft (18) with first, second, third and fourth coupling elements (84, 86, 88, 90) such that they can be engaged and disengaged.

5

11. The gearbox according to any one of the preceding claims, **characterised in** that a first rotor (24) at the first electrical machine (14) is connected to a first ring gear (22) at the first epicyclic gear (10); and

10 that a second rotor (30) at the second electrical machine (16) is connected to a second ring gear (28) at the second epicyclic gear (12).

12. The gearbox according to claim 3, **characterised in** that a first coupling unit (56) is arranged to connect the first sun gear (26) to the first planet gear carrier (50) in a manner that allows them to be separated; and

15 that a second coupling unit (58) is arranged to connect the second sun gear (32) to the second planet gear carrier (51) in a manner that allows them to be separated.

13. The gearbox according to claim 12, **characterised in** that a third coupling unit (59) is arranged to connect the first ring gear (22) at the first epicyclic gear (10) to a gear housing (42) that surrounds the gear housing (2) in a manner that allows them to be separated; and

20 that a fourth coupling unit (61) is arranged to connect a second ring gear (28) at the second epicyclic gear (12) to the gear housing (42) in a manner that allows them to be separated.

14. A vehicle (1), **characterised in** that it comprises a gearbox (2) according to any one of the preceding claims.

25

15. A method to control a gearbox (2), comprising an input shaft (8) and an output shaft (20); a first epicyclic gear (10) that is connected to the input shaft (8); a second epicyclic gear (12) that is connected to the first epicyclic gear (10); a first electrical machine (14) that is connected to the first epicyclic gear (10); a second electrical machine (16) that is connected to the

30 second epicyclic gear (12); a first gear pair (60) that is arranged between the first epicyclic gear (10) and the output shaft (20); and a second gear pair (66) that is arranged between the second epicyclic gear (12) and the output shaft (20), **characterised by** the steps:

- a) to disengage a gear element (92) that is arranged at a side shaft (18) and that is connected through a final gear (21) to the output shaft (20);
- b) to transfer torque from the second epicyclic gear (12) to the side shaft (18) through the second gear pair (66); and
- 5 c) to transfer torque from the side shaft (18) to the output shaft (20) through the first gear pair (60).

16. The method according to claim 15, **characterised by** the further steps:

- d) to drive the second electrical machine (16) with electrical energy generated from the first electrical machine (14) in order to reduce with the second electrical machine (16) the reactive torque from the second epicyclic gear (12), and in order in this way to reduce the torque transferred at the second gear pair (66); and
- 10 e) to increase with the first electrical machine (14) the reactive torque from the first epicyclic gear (10), in order to increase the torque transferred at the first gear pair 60.

15

17. The method according to claim 16, **characterised by** the further steps:

- f) to disengage with a first coupling unit (56) a first sun gear (26) arranged at the first epicyclic gear (10) and a first planet gear carrier (50) from each other; and
- g) to connect with a fourth coupling unit (61) a second ring gear (28) arranged at the second epicyclic gear (12) and a gear housing (42) to each other.
- 20

18. The method according to any one of claims 15-17, **characterised in** that the reduction and the increase in reactive torque at the first and second electrical machines (14, 16) are synchronised, such that the torque at the output shaft (20) is constant or changes in a continuous manner.

25

19. A computer program (P) to control a gearbox, where the said computer program (P) comprises program code to cause an electronic control unit (48) or another computer (53) connected to the electronic control unit (48) to carry out the steps according to any one of claims 15-18.

30

20. A computer product comprising program code stored on a medium that can be read by a computer in order to carry out the method steps according to any one of claims 15-18, when

the said program code is run on an electronic control unit (48) or another computer (53) connected to the electronic control unit (48).

1/4

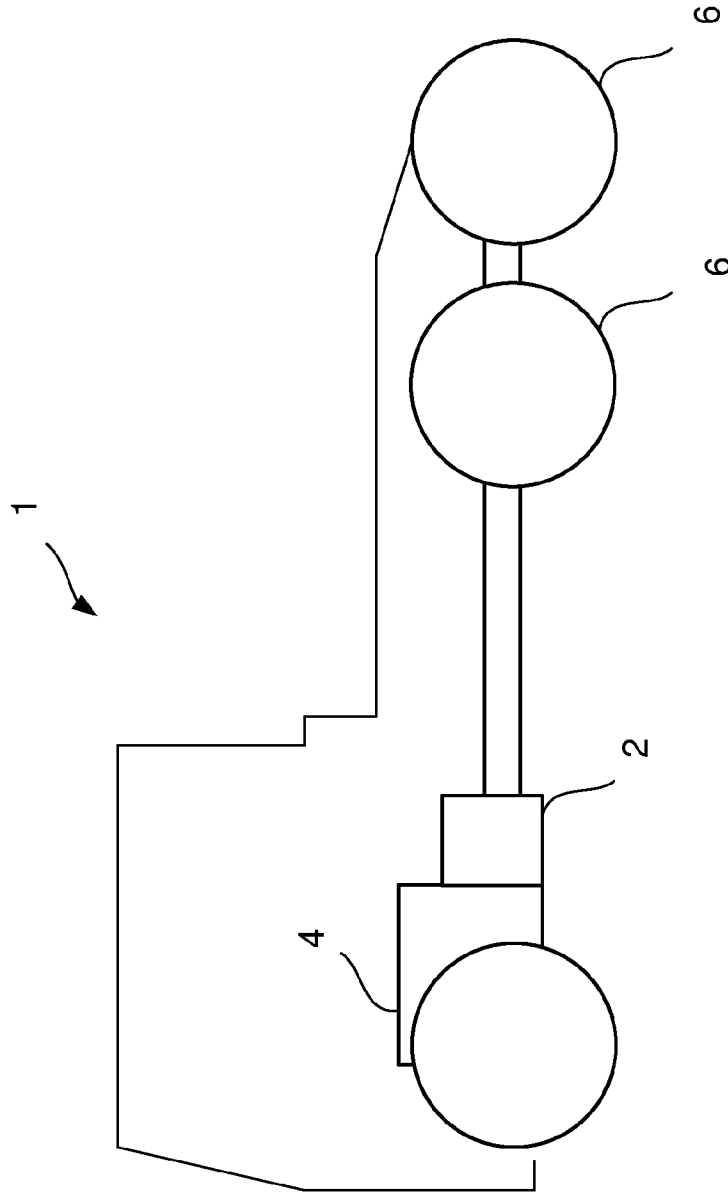


Fig. 1

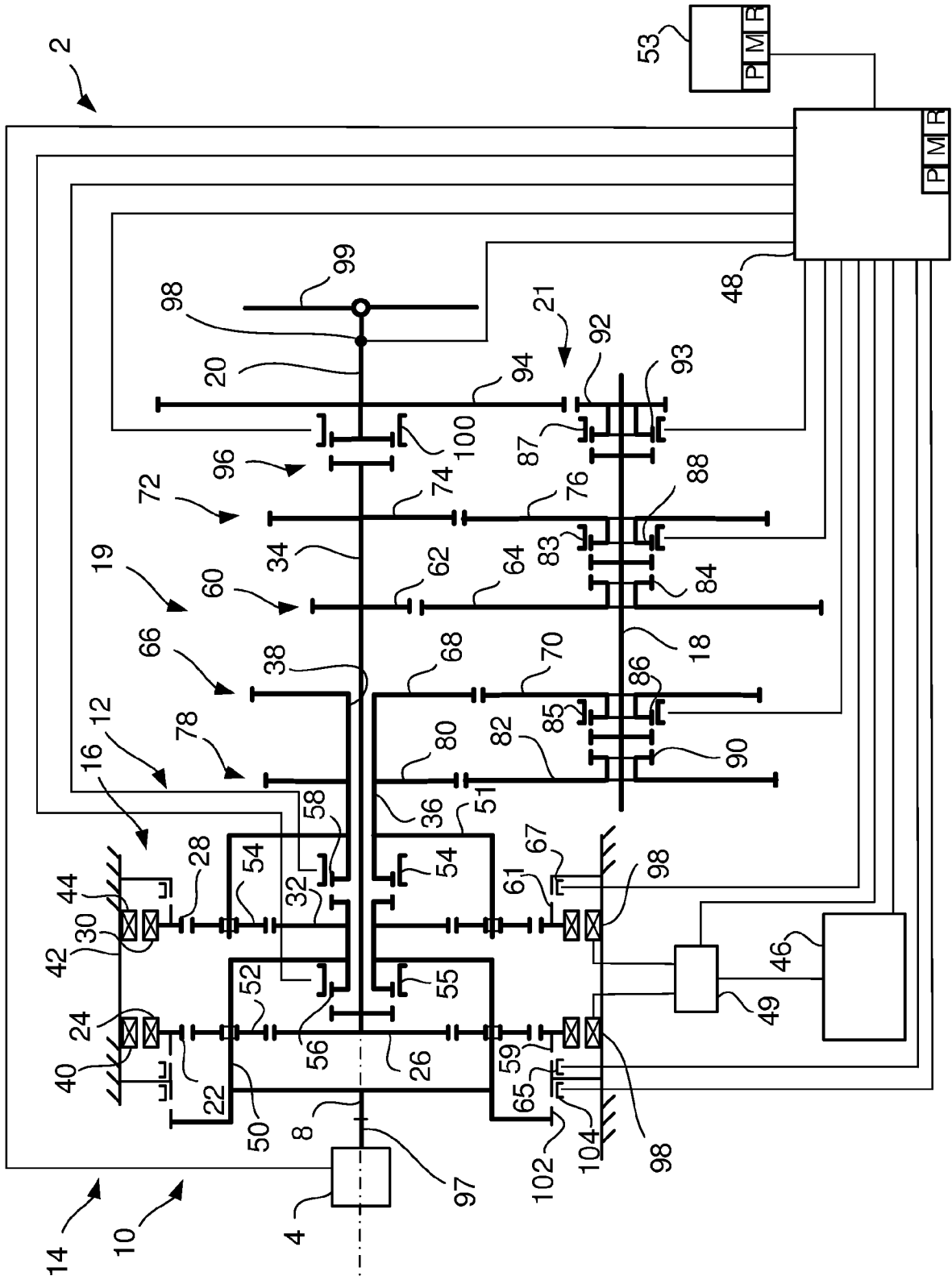


Fig. 2

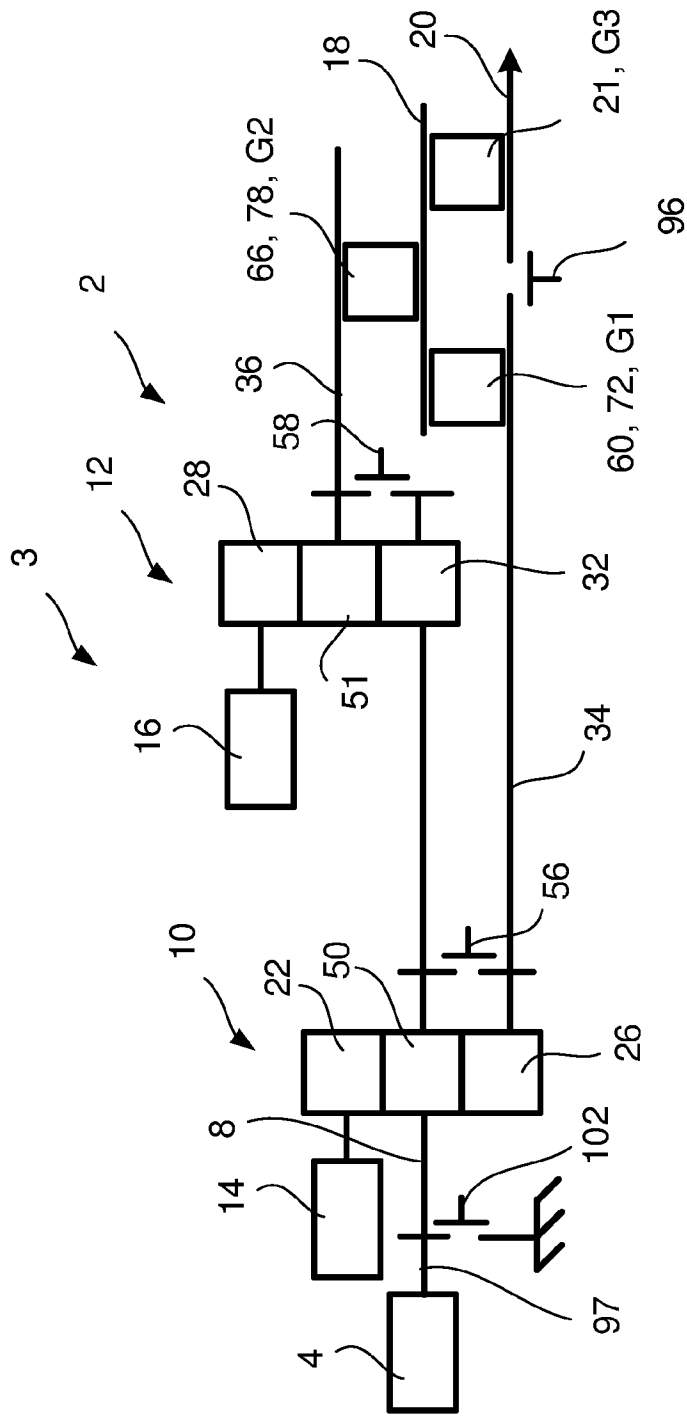


Fig. 3

4/4

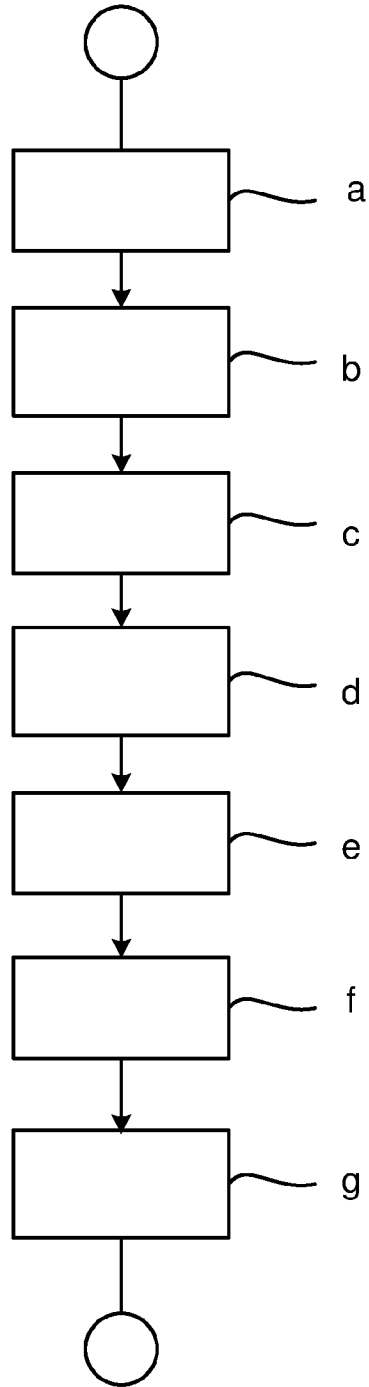


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/050335

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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)

IPC: B60K, B60W, F16H

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

SE, DK, FI, NO classes as above

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

EPO-Internal, PAJ, WPI data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 102008043732 A1 (ZAHNRADFABRIK FRIEDRICHSHAFEN), 18 June 2009 (2009-06-18); paragraphs [0026]-[0030], [0011]-[0013]; figure 1; claims 1, 8 --	1-20
Y	US 20090320629 A1 (AKASHI KOUHEI ET AL), 31 December 2009 (2009-12-31); paragraphs [0020], [0030], [0039]-[0040]; figure 4 --	1-20
A	US 20080064550 A1 (HOLMES ALAN G), 13 March 2008 (2008-03-13); paragraphs [0041]-[0047]; figure 4; claim 6 --	1-20

 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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

03-07-2014

Date of mailing of the international search report

04-07-2014

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2014/050335

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	WO 2007110721 A1 (TOYOTA MOTOR CO LTD ET AL), 4 October 2007 (2007-10-04); abstract; figure 1 --	1-20
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A	EP 1126987 B1 (BOSCH GMBH ROBERT), 29 August 2001 (2001-08-29); abstract; figure 4 --	1-20
A	EP 1280677 B1 (BOSCH GMBH ROBERT), 5 February 2003 (2003-02-05); abstract; figure 4 -- -----	1-20

Continuation of: second sheet

International Patent Classification (IPC)

B60K 6/365 (2007.10)

B60K 1/02 (2006.01)

B60K 6/445 (2007.10)

B60K 6/547 (2007.10)

B60W 10/08 (2006.01)

F16H 3/091 (2006.01)

F16H 3/72 (2006.01)

B60K 6/40 (2007.10)

B60W 20/00 (2006.01)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/SE2014/050335

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