

A METHOD FOR CONTROLLING GEAR SHIFT IN A TRANSMISSION

TECHNICAL FIELD

The invention relates to a method for controlling gear shift in a transmission. In particular,
5 the invention relates to a method for controlling a two-step gear shift in a transmission.
The invention also relates to a control unit for controlling the gear shift and a vehicle
comprising such a transmission. The invention is applicable on vehicles, in particularly
working machines such as e.g. wheel loaders, articulated haulers, dump trucks, etc.
Although the invention will mainly be described in relation to an articulated hauler, it may
10 also be applicable for other type of vehicles such as e.g. trucks.

BACKGROUND

In connection with transportation of heavy loads at construction sites or the like, a working
machine is often used. The working machines may be utilized for transportations in
15 connection with road or tunnel building, sand pits, mines, forestry and similar
environments. Thus, the working machine is frequently operated with large and heavy
loads in rough terrain and on slippery ground where no regular roads are present.

In order to fulfil the desired demands from the fields where the working machine is
frequently operated, high quality of the vehicle gearbox is necessary. The gearbox is
20 arranged for adjusting the speed and tractive effort of the vehicle in dependency of the
specific driving scenario. The gearbox comprises a transmission arrangement and
depending on the specific type of gearbox, the transmission arrangement may comprise
e.g. ordinary gear sets with cylindrical gear wheels in meshed connection with each other
or planetary gear sets comprising a respective sun gear, ring gear and a planet carrier, or
25 a transmission arrangement having a combination of ordinary gear sets and one or more
planetary gear sets.

In addition, these types of transmission arrangements may be operated in several
different manners depending on type of vehicle, terrain, load, and type of operation to be
performed by the vehicle. WO 2017/010919 A1 discloses one type of transmission
30 arrangement, which includes an input shaft, an output shaft, a plurality of planetary gear
sets and a plurality of shift elements being arranged between the input shaft and the
output shaft for providing the desired gear ratios. Moreover, there is disclosed a
transmission arrangement comprising an intermediate gear stage between the second

forward gear and the third forward gear, which increases the variability when choosing the gears to be used.

Although the transmission in WO 2017/010919 A1 provides for the use of an intermediate gear stage between two main gear stages, there is still a need for further improvements in
5 terms of controlling the transmission arrangement in certain occasions.

SUMMARY

It is an object of the present invention to provide a method for controlling a two-step gear shift in a transmission that improves the performance of the transmission in certain
10 occasions, e.g. in an up-hill driving of the vehicle. The object is at least partly achieved by a method according to claim 1.

According to a first aspect of the present invention, there is provided a method for controlling a two-step gear shift in a transmission. The transmission comprises a plurality of shift elements being engageable in combinations to obtain a plurality of gear stages to
15 obtain a set of main gears, defining at least a main gear A, main gear B, main gear C and main gear D. Each one of the main gears has a corresponding gear ratio, the main gears B and C further defining a pair of consecutive main gears, and the main gears A and D defining a pair of adjacent surrounding main gears, and further to obtain at least one auxiliary gear I positioned intermediate the pair of consecutive main gears B and C. The
20 intermediate auxiliary gear I has a gear ratio being intermediate the gear ratios of the pair of consecutive main gears B and C. The method comprises the steps of:

- when selecting one of the main gears A and D of the adjacent surrounding pair of main gears, evaluating a switching from a first gear shifting mode M1 to a second gear shifting mode M2 by determining if a first predetermined vehicle condition is fulfilled, the
25 first gear shifting mode M1 corresponding to a mode in which all main gears of the set of main gears are available, while the intermediate auxiliary gear I is unavailable, and the second gear shifting mode M2 corresponding to a mode in which the intermediate auxiliary gear I is available, while at least the pair of consecutive main gears B and C are unavailable,
- 30 - if the first predetermined vehicle condition is fulfilled, switching from the first gear shifting mode M1 to the second gear shifting mode M2, and
- performing a two-step gear shift from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I, while

excluding one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of the one of the main gears A and D and the gear ratio of the intermediate auxiliary gear I.

In this manner, there is provided a method of using an intermediate gear stage, i.e. the intermediate auxiliary gear I, only at certain occasions when entering an occasional gear shifting mode (i.e. the second gear shifting mode) that deviates from the gear shifting mode normally used (i.e. the first gear shifting mode) in that some main gears are temporarily not available, while the intermediate auxiliary gear I is mandatory to use. The example embodiments of the invention are particularly useful at certain vehicle driving occasions such as driving in hilly terrain, or terrain with varying rolling resistance.

The present invention is based on the insight that one challenge of controlling a transmission of a vehicle at fast changing driving conditions is the problem of rapidly matching the engine rotational speed with the altering speed of the vehicle or the altering power demand. Further, it has been observed that performing only one-step gear shifts (so-called sequential gear shifts) may not be sufficient in some occasions, e.g. when entering an up-hill slope. Rather, two-step gear shifts (so-called skip shifts) may occasionally be needed to provide a more well-balanced performance of the transmission and the vehicle. However, in some types of transmission arrangements, it has been further observed that a two-step gear shift from the fourth forward gear to the second forward gear or from the third forward gear to the first forward gear involves a large ratio step, i.e. about 2.0, which might be troublesome to handle for the system. In addition, a two-step gear shifting may also be performed as a double shift, requiring longer time to execute. That said, the observed gear shifting sequences may also include a one-step gear shift, e.g. from the second forward gear to the first forward gear or from the fourth forward gear to the third forward gear. In these cases, the ratio step may be much smaller and may not be sufficient to maintain the necessary engine power to overcome the slope. As such, when entering an up-hill slope or a terrain with high rolling resistance, various strategies for down-shifting may be applied. However, there may yet be a problem in maintaining sufficient tractive force to keep up speed.

In order to provide a quicker down-shifting with a well-balanced transmission in terms of the ratio steps between the gear stages, the example embodiments of the invention provides a method for operating a transmission arrangement utilizing an intermediate auxiliary gear I between two consecutive main gears, e.g. an intermediate gear stage between the second and third forward main gears. Typically, for one-step gear shifts, the

step between the second forward main gear and the intermediate auxiliary gear I as well as the step between the intermediate auxiliary gear I and the third forward main gear may be too small, especially since these gears are engaged at low vehicle speeds, where larger steps are required than at high vehicle speeds. Accordingly, an alternative gear shifting sequence can be provided by the example embodiments, in which a two-step gear shift is performed, e.g. from the fourth forward main gear to the intermediate auxiliary gear I. Typically, although not strictly required, the transmission may be operated to perform an additional two-step gear shift, i.e. firstly from the fourth forward main gear to the intermediate auxiliary gear I, and secondly from the intermediate auxiliary gear I to the first forward main gear.

In view of the above, the present invention provides a method for using an intermediate auxiliary gear in an alternative gear shifting sequence at certain occasions, i.e. when the transmission is in the second gear shifting mode M2. In this manner, it becomes possible to improve the performance of the transmission in e.g. an up-hill climbing operation, so that the engine rotational speed can more rapidly match the altering speed of the vehicle or the altering power demand. Using the alternative gear shifting sequence of the example embodiments is referred to as entering the second gear shifting mode M2, sometimes also denoted as the occasional gear shifting mode since it is applied only at certain occasions, i.e. when the first predetermined vehicle condition is fulfilled. As mentioned above, the second gear shifting mode M2 deviates from the first gear shifting mode M1, i.e. the gear shifting mode normally used by the vehicle. In particular, the second gear shifting mode M2 differs from the first gear shifting mode M1 in that at least the pair of the consecutive main gears B and C are unavailable, while the intermediate auxiliary gear I is available. Typically, the intermediate auxiliary gear I may be mandatory to use when shifting from one of the main gears A or D. However, in some example embodiments, the intermediate auxiliary gear I is never used outside the second gear shifting mode M2, i.e. outside the occasional gear shifting mode.

Once the intermediate auxiliary gear I is engaged, there are generally only two possible alternatives; either another down-shift to the main gear A or an up-shift back to the main gear D. Thus, the method may further comprise the step of performing an additional two-step gear shift from the intermediate auxiliary gear I to the other main gear A and D of the adjacent surrounding pair of main gears, while excluding the other one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between

the gear ratio of the intermediate auxiliary gear I and the gear ratio of the other main gear of the adjacent surrounding pair of main gears A and D.

Alternatively, the method may further comprise the step of performing a two-step gear shift from the intermediate auxiliary gear I for returning to the one of the adjacent
5 surrounding pair of main gears A and D, while excluding the one of the unavailable main gears B and C of the pair of consecutive main gears having a gear ratio in between the gear ratio of the one of the adjacent surrounding pair of main gears A and D and the gear ratio of the intermediate auxiliary gear I.

As mentioned above, the switching from the first gear shifting mode M1 to the second
10 gear shifting mode M2 is performed by determining if the first predetermined vehicle condition is fulfilled. In other words, entering the second gear shifting mode M2 (the occasional gear shifting mode) is triggered by one or several predefined condition(s).

The first predetermined vehicle condition can be based on several different types of technical information depending on type of vehicle, engine, transmission, installation etc.
15 By way of example, the first predetermined vehicle condition may be any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

In addition, or alternatively, the provision of determining if the first predetermined vehicle condition is fulfilled may comprise the step of comparing a measured first vehicle
20 condition value with a predefined threshold value relating to any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

In other example embodiments, the first predetermined vehicle condition may be fulfilled by a previous gear shifting sequence. The previous gear shifting sequence includes a
25 two-step gear shift to any one of the main gears A and D of the adjacent surrounding pair of main gears.

The alternative gear shifting sequence is typically followed until it is time to exit the occasional gear shifting mode, i.e. no longer operating the transmission in the second gear shifting mode M2. In other words, exiting the second gear shifting mode M2 may be
30 triggered by one or several predefined condition(s). According to one example embodiment, the method further comprises the step of:

- switching from the second gear shifting mode M2 to the first gear shifting mode M1 when a second predetermined vehicle condition is fulfilled.

Also the second predetermined vehicle condition can be based on several different types of technical information depending on type of vehicle, engine, transmission, installation
5 etc. By way of example, the second predetermined vehicle condition may be fulfilled when a gear shifting from the intermediate auxiliary gear I to one of the main gears A and D is performed, or when a gear shifting from one of the main gears A and D to another available main gear of the set of main gears is performed.

By way of another example, the second predetermined vehicle condition may be any one
10 of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

Typically, the provision of determining if the second predetermined vehicle condition is fulfilled may comprise the step of comparing a measured second vehicle condition value with a predefined threshold value relating to any one of a change in vehicle inclination,
15 change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

According to one example embodiment, any one of the first predetermined vehicle condition and the second predetermined vehicle condition may be detected by a vehicle terrain memory function.

20 Typically, although not strictly required, the shifting from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I may be a single shift. In this context, the term single shift refers to a gear shift in which one of the shift elements is shifted from an engaged state to a disengaged state, and another shift element is shifted from a disengaged state to an engaged state.

25 According to one example embodiment, the plurality of shift elements comprises a number of locking elements and a number of connecting elements.

According to one example embodiment, each one of the main gears A, B, C and D, and the intermediate auxiliary gear I is obtainable by positioning one and the same locking element in an engaged state.

According to one example embodiment, each one of the main gears A, D, and the intermediate auxiliary gear I is obtainable by positioning one and the same connecting element in an engaged state.

According to one example embodiment, each one of the main gears A, B, C and D, and
5 the intermediate auxiliary gear I is obtainable by positioning one and the same connecting element in a disengaged state. Typically, in this example embodiment, each one of the main gears A, B, C and D, and the intermediate auxiliary gear I is obtainable also by positioning one and the same locking element in a disengaged state.

According to one example embodiment, the plurality of shift elements is a set of seven
10 shift elements. By way of example, the set of the seven shift elements comprises three locking elements and four connecting elements.

In addition, for each one of the main gears A, B, C and D and the intermediate auxiliary gear I, the method may comprise the step of:

- positioning three of the shift elements in an engaged state.

15 In addition, for each one of the main gears A, B, C and D and the intermediate auxiliary gear I, the method may comprise the step of:

- positioning four of the shift elements in a disengaged state.

According to one example embodiment, the method further comprises the step of:

- positioning the third locking element and the first and third connecting elements in an
20 engaged state when engaging the intermediate auxiliary gear I.

According to one example embodiment, the method further comprises the steps of:

- positioning the first and the third locking elements, and the third connecting element in an engaged state when engaging main gear A;
- positioning the first and the third locking elements, and the fourth connecting element in
25 an engaged state when engaging main gear B;
- positioning the third locking element, and the first and fourth connecting elements in an engaged state when engaging main gear C;

- positioning the third locking element, and the third and fourth connecting elements in an engaged state when engaging main gear D.

Depending on type of vehicle, transmission and engine, the main gears should include an appropriate number of gears. In one example embodiment, the set of main gears
5 comprises nine forward gears and three reverse gears, and the one intermediate auxiliary gear I is an intermediate auxiliary forward gear I.

According to one example embodiment, the pair of consecutive main gears B and C are the second and third forward gears, respectively, the pair of adjacent surrounding main gears A and D are the first and fourth forward gears, respectively, and the intermediate
10 auxiliary gear I is an intermediate auxiliary gear I having a gear ratio intermediate the gear ratios of the second and third forward gears.

In one type of example transmission, the transmission comprises a first, a second, a third, and a fourth planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively, wherein the transmission arrangement further comprises a transmission
15 housing, an input shaft and an output shaft. In this type of transmission;

- the planet carrier of the first planetary gear set and the output shaft are operatively connected to each other;
- the ring gear of the first planetary gear set and the planet carrier of the second planetary gear set are operatively connected to each other;
- 20 - the sun gear of the first planetary gear set and the sun gear of the second planetary gear set are operatively connected to each other;
- the ring gear of the second planetary gear set and the planet carrier of the third planetary gear set are operatively connected to each other; and
- two of the sun gear, the planet carrier and the ring gear of the fourth planetary gear set
25 are each operatively connected to a respective one of the input shaft, the sun gear, the planet carrier and the ring gear of the third planetary gear set.

Planetary gear sets are advantageous as a combination thereof can enable a plurality of gears with various gear ratios. Also, in combination with the plurality of frictional shift elements, the planetary gear sets can relatively smoothly execute gear shifts.

According to a second aspect of the present invention, there is provided a control unit for controlling a two-step gear shift in a transmission, the transmission comprising a plurality of shift elements being engageable in combinations to obtain a plurality of gear stages to obtain a set of main gears, defining at least a main gear A, main gear B, main gear C and
5 main gear D, each one of the main gears having a corresponding gear ratio, the main gears B and C further defining a pair of consecutive main gears, and the main gears A and D defining a pair of adjacent surrounding main gears, and further to obtain at least one auxiliary gear I positioned intermediate the pair of consecutive main gears B and C, the intermediate auxiliary gear I having a gear ratio being intermediate the gear ratios of
10 the pair of consecutive main gears B and C. The control unit is configured to:

- when selecting one of the main gears A and D of the adjacent surrounding pair of main gears, evaluate a switching from a first gear shifting mode M1 to a second gear shifting mode M2 by determining if a first predetermined vehicle condition is fulfilled, the first gear shifting mode M1 corresponding to a mode in which all main gears of the set of main
15 gears are available, while the intermediate auxiliary gear I is unavailable, and the second gear shifting mode M2 corresponding to a mode in which the intermediate auxiliary gear I is available, while at least the pair of consecutive main gears B and C are unavailable,
 - if the first predetermined vehicle condition is fulfilled, switch from the first gear shifting mode M1 to the second gear shifting mode M2, and
 - 20 - perform a two-step gear shift from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I, while excluding one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of the one of the main gears A and D and the gear ratio of the intermediate auxiliary gear I.
- 25 Effects and features of the second aspect are largely analogous to those described above in relation to the first aspect of the present invention.

It should be noted that the control unit may include a microprocessor, microcontroller, programmable digital signal processor or another programmable device. The control unit may also, or instead, include an application specific integrated circuit, a programmable
30 gate array or programmable array logic, a programmable logic device, or a digital signal processor. Where the control unit includes a programmable device such as the microprocessor, microcontroller or programmable digital signal processor mentioned

above, the processor may further include computer executable code that controls operation of the programmable device.

According to a third aspect of the present invention, there is provided a vehicle comprising a prime mover, a transmission and a control unit as described above in relation to the
5 second aspect of the present invention.

According to a fourth aspect of the present invention, there is provided a computer program comprising program code means for performing the steps described above in relation to the first aspect of the present invention when the program is run on a computer.

According to a fifth aspect of the present invention, there is provided a computer readable
10 medium carrying a computer program comprising program means for performing the steps described above in relation to the first aspect of the present invention when the program means is run on a computer.

Effects and features of the third, fourth and fifth aspects are largely analogous to those described above in relation to the first aspect of the present invention.

15 Further features of, and advantages with, the present invention will become apparent when studying the appended claims and the following description. The skilled person realize that different features of the present invention may be combined to create embodiments other than those described in the following, without departing from the scope of the present invention.

20

DEFINITIONS

The relationship between the rotational speeds of the different members in a planetary gear set is defined according to the following:

$$25 \quad \frac{\omega_S - \omega_P}{\omega_R - \omega_P} = R \quad (\text{Eq. 1})$$

wherein

- ω_S is the speed of rotation of the sun gear;
- 30 ω_P is the speed of rotation of the planet carrier;
- ω_R is the speed of rotation of the ring gear; and
- R is the stationary gear ratio of the planetary gear set.

As used herein, the expression “stationary gear ratio” R for a planetary gear set is defined as the ratio of the speed of rotation of the sun gear to the speed of rotation of the ring gear in a situation in which the planet carrier is stationary, i.e.:

5

$$R = -\frac{z_R}{z_S} \quad \text{for single planet gear wheels} \quad (\text{Eq. 2})$$

and

$$10 \quad R = +\frac{z_R}{z_S} \quad \text{for double planet gear wheels} \quad (\text{Eq. 3})$$

wherein

z_R is the number of teeth of the ring gear; and

15 z_S is the number of teeth of the sun gear.

In a similar manner, the expression “ratio” for a transmission should be understood to relate to the number of revolutions of the input shaft of the transmission divided by the number of revolutions of the output shaft of the transmission. Furthermore, the expression
20 “step” should be understood to mean the quotient achieved when the ratio of a gear is divided by the ratio of an adjacent gear of a transmission.

In some examples, a shift element is denoted as an interlocking shift element. In this context, the term “interlocking shift element” should be interpreted as a shift element not able to be positioned in a slipping state. Hence, the interlocking shift element is either
25 positioned in an engaged state or a disengaged state, wherein the engaged state means that the same rotational speed is provided for transmission components on each side of the interlocking shift element. A frictional shift element, on the other hand, can be positioned in an at least partially engaged state, i.e. a slipping state. Interlocking shift elements and frictional shift elements may also be referred to as locking elements and
30 connecting elements, which are arranged for selectively connecting transmission components to each other. The transmission components may e.g. be a transmission housing and/or rotating components of the transmission.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as additional objects, features and advantages of the present invention, will be better understood through the following illustrative and non-limiting
5 detailed description of exemplary embodiments of the present invention, wherein:

Fig. 1 is a lateral side view illustrating a working machine in the form of an articulated hauler;

10 Figs. 2 – 6 schematically illustrate various examples of transmissions according to example embodiments of the present invention;

Figs. 7a – 7b schematically illustrate an example embodiment of the present invention, in which Fig. 7a is a flow chart of a method for controlling a two-step gear shift in the
15 transmission depicted in Figs. 2 – 6, while Fig. 7b is an overview of a gear shifting sequence according to an example embodiment of the present invention; and

Figs. 8a – 8b schematically illustrate an example embodiment of the present invention, in which Fig. 8a is a flow chart of a method for controlling a two-step gear shift in the
20 transmission depicted in Figs. 2 – 6, while Fig. 8b is an overview of a gear shifting sequence according to an example embodiment of the present invention.

With reference to the appended drawings, below follows a more detailed description of embodiments of the invention cited as examples.

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DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS OF THE INVENTION

The present invention will now be described more fully hereinafter with reference to the
30 accompanying drawings, in which exemplary embodiments of the invention are shown.

The invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness. Like reference character refer to like elements throughout the description.

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Fig. 1 is a side view of a working machine 201 in the form of an articulated hauler having a tractor unit 202 with a cab 203 for a driver and a trailer unit 204 with a platform having a dump body 205, here in the form of a container, arranged thereon, for receiving load. The dump body 205 is preferably pivotally connected to the rear section and tiltable by means of a pair of tilting cylinders 206, for example hydraulic cylinders. The tractor unit 202 has a frame 207 and a pair of wheels 208 suspended from the frame 207. The trailer unit 204 has a frame 209 and two pair of wheels 210, 211 suspended from the frame 209.

The working machine is frame-steered, i.e. there is a joint arrangement 212 connecting the tractor unit 202 and the trailer unit 204 of the working machine 201. The tractor unit 202 and the trailer unit 204 are pivotally connected to each other for pivoting around a substantially vertical pivot axis 213.

The working machine preferably comprises a hydraulic system having two hydraulic cylinders 214, steering cylinders, arranged on opposite sides of the working machine for turning the working machine by means of relative movement of the tractor unit 202 and the trailer unit 204. The hydraulic cylinders can, however, be replaced by any other linear actuator for steering the machine, such as an electromechanical linear actuator.

Furthermore, the articulated hauler comprises a prime mover 216, here illustrated as an internal combustion engine, and a gearbox 218 having a transmission arrangement according to any one of the example embodiments described below in relation to Figs. 2 – 6 and further configured to perform a method according to any one of the example embodiments described below in relation to Figs. 7a – 7b and 8a – 8b. Furthermore, the articulated hauler also comprises a control unit 600 for controlling the below described transmissions. The control unit 600 may be, or form part of, already existing control units for controlling the gearbox.

In the following description, it should be readily appreciated that the plurality of frictional shift elements will also be described in terms of connecting elements and locking elements, where a connecting element is arranged to connect at least two rotating planetary members to each other or at least one rotating planetary member to an input shaft or an output shaft, and a locking element is arranged to lock at least one rotating planetary member to a transmission housing.

Now, with reference to Fig. 2, an example embodiment of a transmission 100 according to the present invention is illustrated. The transmission 100 comprises a first planetary gear set 102 comprising a sun gear 102S, a planet carrier 102P and a ring gear 102R, a second planetary gear set 104 comprising a sun gear 104S, a planet carrier 104P and a ring gear 104R, a third planetary gear set 106 comprising a sun gear 106S, a planet carrier 106P and a ring gear 106R, and a fourth planetary gear set 108 comprising a sun gear 108S, a planet carrier 108P and a ring gear 108R. The transmission 100 further comprises an input shaft 136 for receiving a rotary motion/torque from the prime mover 216 of the vehicle 201 and an output shaft 112 for providing a rotary motion/torque to the driven wheels of the vehicle 201.

The different members of the planetary gear sets 102, 104, 106, 108 of the transmission 100, i.e. the sun gear, the planet carrier and the ring gear, are in the example embodiment depicted in Fig. 2 configured according to the following description. It should be readily understood that the different members described below are connected to each other, either directly, i.e. operatively connected, or via a shift element, i.e. selectively connectable. The members can be operatively connected to each other by means of e.g. a connector element. Such connector element can be e.g. a solid shaft, a hollow shaft or a drum, or other suitable element for connecting two members to each other, which elements are known to the person skilled in the art. Hence, no explicit explanation is given below in regards to the means connecting the members to each other.

The planet carrier 102P of the first planetary gear set 102 is operatively connected to the output shaft 112 of the transmission 100, i.e. the planet carrier 102P is at all times directly connected to the output shaft 112 of the transmission 100. Further, the ring gear 102R of the first planetary gear set 102 is operatively connected to the planet carrier 104P of the second planetary gear set 104. The sun gear 102S of the first planetary gear set 102 is operatively connected to the sun gear 104S of the second planetary gear set 104. Furthermore, the sun gear 102S of the first planetary gear set 102 and the sun gear 104S of the second planetary gear set 104 are selectively connectable to a transmission housing 160 of the transmission 100 by means of a frictional shift element in the form of a third locking element 142. Hence, the third locking element 142, when being engaged, initially reduces the rotational speed of the respective sun gears 102S, 104S, and thereafter locks the respective sun gears 102S, 104S to the transmission housing 160.

The ring gear 104R of the second planetary gear set 104 is operatively connected to the planet carrier 106P of the third planetary gear set 106. Furthermore, the planet carrier 104P of the second planetary gear set 104 is selectively connectable to the sun gear 106S of the third planetary gear set 106 by means of a frictional shift element in the form of a second connecting element 144. Furthermore, the planet carrier 104P of the second planetary gear set 104 is also selectively connectable to the ring gear 106R of the third planetary gear set 106 by means of a frictional shift element in the form of a first connecting element 146. Moreover, the planet carrier 104P of the second planetary gear set 104 is selectively connectable to the transmission housing 160 by means of a second locking element 140. The second locking element 140 is typically designed as a frictional shift element. In another example, the second locking element may be an interlocking shift element, as shown in Figs. 2 – 6. The second locking element 140 may, for example, be designed as a dog clutch. The second locking element 140, when being engaged, locks the planet carrier 104P to the transmission housing 160.

The sun gear 106S of the third planetary gear set 106 is operatively connected to the ring gear 108R of the fourth planetary gear set 108. The ring gear 106R of the third planetary gear set 106 is operatively connected to the sun gear 108S of the fourth planetary gear set 108. The ring gear 106R of the third planetary gear set 106 and the sun gear 108S of the fourth planetary gear set 108 are selectively connectable to the transmission housing 160 by means of a frictional shift element in the form of a first locking element 138. Hence, the first locking element 138, when being engaged, initially reduces the rotational speed of the ring gear 106R and the sun gear 108S, and thereafter locks the ring gear 106R and the sun gear 108S to the transmission housing 160.

Finally, the input shaft 136 is selectively connectable to the ring gear 108R of the fourth planetary gear set 108 and to the sun gear 106S of the third planetary gear set 106 by means of a frictional shift element in the form of a third connecting element 148, and selectively connectable to the planet carrier 108P of the fourth planetary gear set 108 by means of a frictional shift element in the form of a fourth connecting element 150.

According to the example embodiment depicted in Fig. 2, the stationary gear ratio of each one of the first 102, second 104, third 106, and fourth 108 planetary gear sets are negative. According to a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 1.

Table 1 – Exemplary stationary gear ratios for the embodiment depicted in Fig. 2.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
-2.825	-1.625	-1.700	-2.650

With reference to Fig. 3, another example embodiment of the transmission 200 is depicted. The transmission 200 of the example embodiment depicted in Fig. 3 is in many ways similar to the transmission 100 depicted in Fig. 2. Therefore, the following will mainly describe those parts that differ from the transmission 100 in Fig. 2.

The planet carrier 108P of the fourth planetary gear set 108 is operatively connected to the input shaft 136 of the transmission 200. Moreover, the ring gear 106R of the third planetary gear set 106 is operatively connected to the sun gear 108S of the fourth planetary gear set 108. Further, the sun gear 106S of the third planetary gear set 106 is selectively connectable to the input shaft 136 by means of a frictional shift element in the form of a third connecting element 148, and selectively connectable to the ring gear 108R of the fourth planetary gear set 108 by means of a frictional shift element in the form of a fourth connecting element 150.

According to the example embodiment depicted in Fig. 3, the stationary gear ratio of each one of the first 102, second 104, third 106, and fourth 108 planetary gear sets are negative. According to a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 2.

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Table 2 – Exemplary stationary gear ratios for the embodiment depicted in Fig. 3.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
-2.825	-1.625	-1.700	-2.650

With reference to Fig. 4, another example embodiment of the transmission 300 is depicted. The transmission 300 of the example embodiment depicted in Fig. 4 is in many ways similar to the transmissions depicted in Figs. 2 and 3. Therefore, the following will mainly describe the differences compared to those transmissions.

The sun gear 106S of the third planetary gear set 106 is operatively connected to the ring gear 108R of the fourth planetary gear set 108. Also, the planet carrier 108P of the fourth

planetary gear set 108 is operatively connected to the input shaft 136 of the transmission 300. Furthermore, the sun gear 108S of the fourth planetary gear set 108 is selectively connectable to the input shaft 136 and to the planet carrier 108P of the fourth planetary gear set 108 by means of a frictional shift element in the form of a third connecting
 5 element 148. Finally, the ring gear 106R of the third planetary gear set 106 is selectively connectable to the sun gear 108S of the fourth planetary gear set 108 by means of a frictional shift element in the form of a fourth connecting element 150.

According to the example embodiment depicted in Fig. 4, the stationary gear ratio of each
 10 one of the first 102, second 104, third 106, and fourth 108 planetary gear sets are negative. According to a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 3.

Table 3 – Exemplary stationary gear ratios for the embodiment depicted in Fig. 4.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
-2.825	-1.625	-1.700	-2.650

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With reference to Fig. 5, another example embodiment of the transmission 400 is depicted. The transmission 400 of the example embodiment depicted in Fig. 5 is in many ways similar to the transmissions described above and the following will therefore mainly describe the differences compared to those transmissions.

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The sun gear 106S of the third planetary gear set 106 is operatively connected to the planet carrier 108P of the fourth planetary gear set 108. Also, the planet carrier 106P of the third planetary gear set 106 is operatively connected to the sun gear 108S of the fourth planetary gear set 108. Furthermore, the input shaft 136 is selectively connectable
 25 to the sun gear 106S of the third planetary gear set 106 and to the planet carrier 108P of the fourth planetary gear set 108 by means of a frictional shift element in the form of a third connecting element 148, and selectively connectable to the ring gear 108R of the fourth planetary gear set 108 by means of a frictional shift element in the form of a fourth connecting element 150.

30

According to the example embodiment depicted in Fig. 5, the stationary gear ratio of each one of the first 102, second 104 and third 106 planetary gear sets are negative. The

stationary gear ratio of the fourth planetary gear set 108 is however positive. According to a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 4.

5 Table 4 – Exemplary stationary gear ratios for the embodiment depicted in Fig.5.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
-2.825	-1.625	-1.700	2.300

Finally, with reference to Fig. 6, another example embodiment of the transmission 500 is depicted. The transmission 500 of the example embodiment depicted in Fig. 6 is in many ways similar to the transmissions described above and the following will therefore mainly
 10 describe the differences compared to those transmissions.

The sun gear 106S of the third planetary gear set 106 is operatively connected to the sun gear 108S of the fourth planetary gear set 108. Also, the planet carrier 106P of the third planetary gear set 106 is operatively connected to the planet carrier 108P of the fourth
 15 planetary gear set 108. Furthermore, the input shaft 136 is selectively connectable to the sun gear 106S of the third planetary gear set 106 and to the sun gear 108S of the fourth planetary gear set 108 by means of a frictional shift element in the form of a third connecting element 148, and selectively connectable to the ring gear 108R of the fourth
 20 planetary gear set 108 by means of a frictional shift element in the form of a fourth connecting element 150.

According to the example embodiment depicted in Fig. 6, the stationary gear ratio of each one of the first 102, second 104 and third 106 planetary gear sets are negative. The stationary gear ratio of the fourth planetary gear set 108 is however positive. According to
 25 a non-limiting example, the stationary gear ratio for each of the planetary gear sets may be as described below in Table 5.

Table 5 – Exemplary stationary gear ratios for the embodiment depicted in Fig.6.

First planetary gear set (102)	Second planetary gear set (104)	Third planetary gear set (106)	Fourth planetary gear set (108)
-2.825	-1.625	-1.700	1.770

Since the fourth planetary gear set 108 has a positive stationary gear ratio and the fact that the planet carrier 108P of the fourth planetary gear set 108 is operatively connected to the planet carrier 106P of the third planetary gear set 106, and that the sun gear 108S of the fourth planetary gear set 108 is operatively connected to the sun gear 106S of the third planetary gear set 106, the third 106 and fourth 108 planetary gear sets can be designed as a compound planetary gear set of Ravigneaux type.

The above described example embodiments depicted in Figs. 2 – 6 are adapted to assume the gears as presented in Table 6 below. The transmissions depicted in Figs. 2 – 6 assume nine forward gears and three reverse gears. In Table 6 below, the locking elements are denoted simply as “Brakes” while the connecting elements are denoted simply as “Clutches”. A cell marked with a dot indicates an engaged state and a blank cell indicates a disengaged state. Furthermore, Table 6 also indicates non-limiting examples of the gear ratios and steps obtainable by the transmission for the various gears. The gear ratios and steps presented in Table 6 are derived from the exemplary stationary gear ratios presented in Tables 1 – 5 above.

Table 6 – Shift diagram, gear ratios and steps for the different gears.

Gear	Brakes			Clutches				Ratio	Step
	138	140	142	148	150	144	146		
1	•		•	•				5.91	1.38
2	•		•		•			4.29	1.44
3			•		•		•	2.99	1.37
4			•	•	•			2.19	1.27
5			•		•	•		1.72	1.27
6			•	•		•		1.35	1.35
7				•	•	•		1.00	1.27
8	•			•		•		0.79	1.38
9	•				•	•		0.57	
R1		•		•			•	-6.36	1.38
R2		•			•		•	-4.61	1.96
R3		•		•	•			-2.35	

20

As depicted in Table 6 above, the transmissions in Figs. 2 – 6 comprise nine forward gears and three reverse gears (indicated with an R). The shifting of gears can preferably be executed by one-step gear shifts or with two-step gear shifts. One-step gear shift should be understood to mean that a gear shift is executed from one gear to the next coming consecutive gear, for example, gear shift from the first gear to the second gear, from the second gear to the third gear, from the third gear to the second gear, etc. Two-step gear shift should be understood to mean that a gear shift is executed to exclude a

next coming consecutive gear, for example, gear shift from the first gear to the third gear, from the second gear to the fourth gear, from the third gear to the first gear, etc.

As can be seen from Table 6, one-step gear shifting includes only single shifts of the
5 connecting elements and the locking elements, i.e. when executing one-step gear shifts, only one of the connecting elements/locking elements is shifted from an engaged state to a disengaged state, and only one of the connecting elements/locking elements is shifted from a disengaged state to an engaged state. As an example, when shifting from the first forward gear to the second forward gear, it is only the third connecting element 148 that is
10 changed from an engaged state to a disengaged state, and only the fourth connecting element 150 that is changed from a disengaged state to an engaged state.

Furthermore, and as is depicted in Table 6, there is only one occasion during two-step gear shifts where double shift occurs. Double shift should be understood to mean that two
15 connecting elements/locking elements are changed from an engaged state to a disengaged state, and two connecting elements/locking elements are changed from a disengaged state to an engaged state. For two-step gear shifts, this occurs when shifting from the first forward gear to the third forward gear, or vice versa from the third gear to the first gear. When shifting from the first gear to the third gear, the first locking element 138
20 and the third connecting element 148 are changed from an engaged state to a disengaged state, and the first 146 and the fourth 150 connecting elements are changed from a disengaged state to an engaged state.

An advantage of the transmission according to the examples above is that a low number
25 of connecting elements/locking elements need activation/deactivation during gear shifting. That is, during one-step gear shifting only single shifts occur and during two-step gear shifting only one double shift occurs, which is when shifting gears between the first and third forward gears of the transmission.

30 Furthermore, it should also be noted from Table 6 that the second locking element 140 is positioned in a disengaged state for all the forward gears and positioned in an engaged state for all of the reverse gears.

Moreover, with the above described example embodiments of the transmission
35 arrangement, a further auxiliary gear is obtainable. Table 7 below illustrates one auxiliary

gear that is possible to obtain by the connecting elements and locking elements depicted and described above. In Table 7, the auxiliary gear 2.5* is an additional gear with a gear ratio between the gear ratios of the second and third main gears.

- 5 If using the above described nine forward gears depicted in Table 6 with the auxiliary gear 2.5* depicted in Table 7, only single shifts occur for two-step gear shifts and one double shift occurs for one-step gear shifts. The double shift for the one-step gear shift occurs when shifting from the second main gear to the auxiliary gear 2.5*, wherein the first locking element 138 and the fourth connecting element 150 are changed from an engaged state to a disengaged state, and the first 146 and the third 148 connecting elements are changed from a disengaged state to an engaged state.

Table 7 – Shift diagram, gear ratios and steps for the different gears.

		Brakes			Clutches			Ratio	Step
Gear		138	140	142	148	150	144		
A	1	•		•	•			5.91	1.38
B	2	•		•		•		4.29	1.19
I	2.5*			•	•		•	3.60	1.20
C	3			•		•	•	2.99	1.37
D	4			•	•	•		2.19	1.27
E	5			•		•	•	1.72	1.27
F	6			•	•		•	1.35	1.35
	7				•	•	•	1.00	1.27
	8	•			•		•	0.79	1.38
	9	•				•	•	0.57	
	R1		•		•		•	-6.36	1.38
	R2		•			•	•	-4.61	1.96
	R3		•		•	•		-2.35	

Hence, with the transmission arrangements depicted and described in relation to Figs. 2 – 6, it becomes possible to obtain an additional auxiliary gear. A further example advantage is thus that the transmission arrangement according to the examples described above provides for an increased variability when choosing the gears to be used.

One challenge of controlling a transmission of a vehicle at fast changing driving conditions is the problem of rapidly matching the engine rotational speed with the altering speed of the vehicle or the altering power demand. When driving in hilly terrain or terrain with varying rolling resistance, skip-shifting may be needed.

The tables 8 and 9 below illustrate two different gear shifting sequences, including one or more skip-shifts.

Table 8 – Shift diagram, gear ratios and steps for a first gear shifting sequence using main gears.

Gear	Brakes			Clutches				Ratio	Step
	138	140	142	148	150	144	146		
1	•		•	•				5.91	1.38
2	•		•		•			4.29	
4			•	•	•			2.19	1.96
6			•	•		•		1.35	1.62

Table 9 – Shift diagram, gear ratios and steps for a second gear shifting sequence using main gears.

Gear	Brakes			Clutches				Ratio	Step
	138	140	142	148	150	144	146		
1	•		•	•				5.91	1.98
3			•		•		•	2.99	
4			•	•	•			2.19	1.37
6			•	•		•		1.35	1.62

As may be noted from the tables 8 and 9 above, a two-step gear shift (i.e. a skip shifting) from the fourth forward main gear (gear 4) to the second forward main gear (gear 2) or from the third forward main gear (gear 3) to the first forward main gear (gear 1) involves a large ratio step, i.e. about 2.0, which might be troublesome to handle for the system. In addition, a two-step gear shifting may also be performed as a double shift, requiring longer time to execute. With reference to table 9 above, the two-step gear shift from the third forward main gear (gear 3) to the first forward main gear (gear 1) is one example of a two-step gear shifting performed as double shift. The gear shifting sequences may also include a respective sequential gear shift, e.g. from the second forward main gear (gear 2) to the first forward main gear (gear 1) or from the fourth forward main gear (gear 4) to the third forward main gear (gear 3). In these cases, the ratio step may be much smaller and may not be sufficient to maintain the necessary engine power to overcome a slope.

An alternative gear shifting sequence is illustrated in table 10 below, in which the intermediate auxiliary gear (gear 2.5*) is used. As may be noted in the table, two skip shifts (two two-step gear shifts) are performed, counting from the fourth forward main gear (gear 4), firstly from the fourth forward main gear (gear 4) to the intermediate auxiliary gear (gear 2.5*), and secondly from the intermediate auxiliary gear (gear 2.5*) to the first forward main gear (gear 1).

Table 10 – Shift diagram, gear ratios and steps for an alternative gear shifting sequence using an intermediate auxiliary gear.

Gear	Brakes			Clutches				Ratio	Step
	138	140	142	148	150	144	146		
1	•		•	•				5.91	
2.5*			•	•			•	3.60	1.64
4			•	•	•			2.19	1.64
6			•	•		•		1.35	1.62

As can be noted from the table 10 above, the ratio steps are more well-balanced

- 5 compared to the ratio steps in tables 8 and 9. Further, the gear shifting is performed without any double shifts.

In the following, a method for this gear shifting sequence will be described in relation to Figs. 7a-7b and 8a-8b. That is, Fig. 7a illustrates a flowchart for controlling a two-step
 10 gear shift in the transmissions as described in relation to the Figs. 2-6, thus reflecting the steps of the method according to the example embodiments of the invention, while Fig. 7b illustrates further details of the two-step gear shift when the transmission is in the second gear shifting mode. In Fig. 7b, the gear shifts are indicated by arrows and dashed arrows to facilitate the understanding of the gear shifts performed by the method. Fig. 8a
 15 illustrates another example of a flowchart for controlling a two-step gear shift in the transmissions as described in relation to the Figs. 2-6, while Fig. 8b illustrates further details of this example similar to Fig. 7b.

In other words, there is provided a method for controlling a two-step gear shift in a transmission 100, 200, 300, 400, 500. As mentioned above, the transmission here
 20 comprises the plurality of shift elements 138, 140, 142, 144, 146, 148, 150 being engageable in combinations to obtain the plurality of gear stages to obtain a set of main gears. In particular, the number of shift elements is seven, i.e. three locking elements 138, 140, 142 and four connecting elements 144, 146, 148, 150.

As shown in Fig. 7b, the main gears are here defined as a main gear A, a main gear B, a
 25 main gear C, a main gear D, a main gear E and a main gear F. Each one of the main gears has a corresponding gear ratio. In this example, the main gears correspond to the first six gears as presented in the table 6 above. That is, the main gear A corresponds to the first forward gear (gear 1), the main gear B corresponds to the second forward gear (gear 2), the main gear C corresponds to the third forward gear (gear 3), the main gear D
 30 corresponds to the fourth forward gear (gear 4), the main gear E corresponds to the fifth

forward gear (gear 5) and the main gear F corresponds to the sixth forward gear (gear 6). However, it should be readily appreciated that the main gears A-F may likewise correspond to other main gears or other sequences of main gears obtainable from the transmission described above or other transmissions, while the main gears A-F typically
5 refer to a number of main gears following a sequence.

Further, the main gears B and C define a pair of consecutive main gears. In this context, the term "pair of consecutive" refers to any one of two primary (main) gears of the transmission having sequential adjacent main gear ratios. For instance, gear 2 and gear 3 form a pair of consecutive main gears, gear 5 and gear 6 form a pair of consecutive main
10 gears, gear 6 and gear 7 form a pair of consecutive main gears, etc. Note that the term pair of consecutive main gears here refers to the main gears of any transmission, and in particular the transmission depicted in the Figs. 2-6 and described in relation to the tables 6 and 7. In that case, the main gears refer to the nine forward gears 1, 2, 3, 4, 5, 6, 7, 8 and 9 and the three reverse gears R1, R2 and R3. Thus, it should be readily appreciated
15 that the term "the pair of consecutive main gears B and C", as used herein, may refer to any one of a pair of consecutive main gears of the main set of gears, and thus not only to the second forward gear (gear 2) and the third forward gear (gear 3) as mentioned above in the described example embodiments of the method.

In addition, the main gears A and D define a pair of adjacent surrounding main gears. In
20 this context, the term "pair of adjacent surrounding" refers to any one of two primary (main) gears of the transmission having corresponding main gear ratios being successive in order relative to the main gear ratios of the pair of consecutive main gears. In addition, the pair of adjacent surrounding main gears is arranged on each side of the main gears of the pair of the consecutive main gears, respectively. For instance, gear 1 and gear 4 form
25 a pair of adjacent surrounding main gears to the pair of consecutive main gears 2 and 3, gear 4 and gear 7 form a pair of adjacent surrounding main gears to the pair of consecutive main gears 5 and 6 etc. Note that the term pair of adjacent surrounding main gears here refers to the main gears of any transmission, and in particular the transmission depicted in the Figs. 2-6 and described in relation to the tables 6 and 7. In that case, the
30 main gears refers to the nine forward gears 1, 2, 3, 4, 5, 6, 7, 8 and 9 and the three reverse gears R1, R2 and R3. Thus, it should be readily appreciated that the term "the pair of adjacent surrounding main gears A and D", as used herein, may refer to any one of a pair of adjacent surrounding main gears of the main set of gears, and thus not only to

the first forward gear (gear 1) and the fourth forward gear (gear 4) as mentioned above in the described example embodiments of the method.

As mentioned above, the plurality of the shift elements 138, 140, 142, 144, 146, 148, 150 are also engageable in combinations to obtain at least one auxiliary gear I being positioned intermediate the pair of consecutive main gears B and C. The intermediate auxiliary gear I has a gear ratio being intermediate the gear ratios of the pair of consecutive main gears B and C. In this example, the intermediate auxiliary gear I corresponds to the gear 2.5* as presented in the table 7 above. However, it should be readily appreciated that the intermediate auxiliary gear I may correspond to an intermediate auxiliary gear I positioned intermediate another pair of consecutive main gears obtainable from any transmission, and in particular the transmission described above.

In this example, as mentioned above, the set of main gears comprises nine forward gears and three reverse gears, and the one intermediate auxiliary gear I is an intermediate auxiliary forward gear I. Thus, in this example, the pair of consecutive main gears B and C corresponds to the second and third forward gears, respectively, the pair of adjacent surrounding main gears A and D corresponds to the first and fourth forward gears, respectively, and the intermediate auxiliary gear I corresponds to an intermediate auxiliary gear having a gear ratio intermediate the gear ratios of the second and third forward gears.

Turning again to Figs. 7a and 7b, a method 800 according to one example embodiment of the present invention is illustrated.

In step 820, when one of the main gears A and D of the adjacent surrounding pair of main gears is selected, the method evaluates a switching from a first gear shifting mode M1 to a second gear shifting mode M2 by determining if a first predetermined vehicle condition is fulfilled. In this context, the first gear shifting mode M1 corresponds to a mode in which all main gears of the set of main gears are available, while the intermediate auxiliary gear I is unavailable. In addition, in this context, the second gear shifting mode M2 corresponds to a mode in which the intermediate auxiliary gear I is available, while at least the pair of the consecutive main gears B and C are unavailable. It should be noted that in this step, and when the transmission is in the second gear shifting mode M2, the other main gears of the set of main gears remain available. In this example, this means that at least the main gears A, D, E and F are maintained available. Typically, the step 820 is executed by

the control unit 600. Generally, although not strictly required, the availability and the unavailability of the main gears are set by the control unit of the transmission, or a control unit of the vehicle.

- 5 In the example in Fig. 7b, this step corresponds to a position when the main gear D is selected. Then, the method evaluates a switch from the first gear shifting mode M1 to the second gear shifting mode M2 by determining if the first predetermined vehicle condition is fulfilled. In this example, the first predetermined vehicle condition is a change in vehicle inclination. For example, the vehicle inclination is monitored by a sensor adapted to
10 communicate with the control unit 600 and to send information about the change in vehicle inclination to the control unit. The control unit is further configured to evaluate the information and determine whether the first predetermined vehicle condition is fulfilled based on the information received from the sensor. If the control unit determines that the predetermined vehicle condition is fulfilled, the control unit is configured to execute the
15 following/additional steps and sequences in the method, as further described hereinafter. However, the first predetermined vehicle condition may be related to another type of condition. By way of example, the first predetermined vehicle condition may be any one of a change in vehicle inclination, change in rolling resistance between tires and ground, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position,
20 or a combination thereof.

In another example embodiment of the method, although not shown, the step of determining if the first predetermined vehicle condition is fulfilled comprises the step of comparing a measured first vehicle condition value with a predefined threshold value. The predefined threshold value here relates to any one of a change in vehicle inclination,
25 change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

In yet another example embodiment, as indicated by the dashed arrow in Fig. 7b, the first predetermined vehicle condition may alternatively be fulfilled by a previous gear shifting sequence, the previous gear shifting sequence including a two-step gear shift to any one
30 of the main gears A and D of the adjacent surrounding pair of main gears. That is, in the example in Fig. 7b, the previous gear shifting sequence corresponds to the two-step gear shift to the main gear D from the main gear F.

In step 830, the method switches from the first gear shifting mode M1 to the second gear shifting mode M2 if the first predetermined vehicle condition is fulfilled. Typically, the step 830 is also executed by the control unit 600.

When the transmission is set to operate in the second gear shifting mode M2, the transmission performs a two-step gear shift 840. In step 840 a two-step gear shift from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I is performed, while excluding one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of the one of the main gears A and D and the gear ratio of the intermediate auxiliary gear I. Also step 840 is here executed by the control unit 600.

Also, the shifting from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I is typically a single shift.

In the example in Fig. 7b, this step corresponds to performing a two-step gear shift from the main gear D to the intermediate auxiliary gear I, while excluding the unavailable main gear C. In this example, the main gear C has a gear ratio in between the gear ratio of the main gear D and the gear ratio of the intermediate auxiliary gear I. The two-step gear shift from the main gear D to the intermediate auxiliary gear I is here a single shift, as described above.

When step 840 is performed, the vehicle may in some occasions be operated to maintain the intermediate auxiliary gear I engaged for a certain time. This example of the method is illustrated in Fig. 8a and Fig. 8b. Alternatively, the transmission may be controlled to perform an additional two-step gear shift.

For example, the method may continue to perform the step 850 or step 860, as described below.

In step 850, an additional two-step gear shift is performed from the intermediate auxiliary gear I to the other main gear A and D of the adjacent surrounding pair of main gears, while excluding the other one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of the intermediate auxiliary gear I and the gear ratio of the other main gear of the adjacent surrounding pair of main gears A and D. In the example in Fig. 7b, this step corresponds to an additional two-step gear shift from the intermediate auxiliary gear I to the main gear A, while

excluding the main gear B. In this example, the main gear B has a gear ratio in between the gear ratio of the intermediate auxiliary gear I and the gear ratio of the main gear A.

Alternatively, the method may continue to perform the step 860. In step 860 an additional two-step gear shift is performed from the intermediate auxiliary gear I for returning to the
5 one of the adjacent surrounding pair of main gears A and D, while excluding the one of the unavailable main gears B and C of the pair of consecutive main gears having a gear ratio in between the gear ratio of the one of the adjacent surrounding pair of main gears A and D and the gear ratio of the intermediate auxiliary gear I. In the example in Fig. 7b, this step corresponds to an additional two-step gear shift from the intermediate auxiliary gear I
10 for returning to the main gear D, while excluding the main gear C. Main gear C has a gear ratio in between the gear ratio of the main gear D and the gear ratio of the intermediate auxiliary gear I, as stated above in relation to step 840.

Exiting the occasional gear shifting mode, i.e. the second gear shifting mode M2 can occur in several different ways. Typically, exiting the second gear shifting mode is
15 executed similar to entering the second gear shifting mode, i.e. by a predetermined vehicle condition. Thus, in some example embodiments, the method comprises the step of exiting the second gear shifting mode M2 when another vehicle condition is fulfilled. In other words, and as illustrated in Fig. 7a, the method here further comprises the step 870 of switching from the second gear shifting mode M2 to the first gear shifting mode M1
20 when a second predetermined vehicle condition is fulfilled.

In this example, the second predetermined vehicle condition is fulfilled when a gear shifting from the intermediate auxiliary gear I to one of the main gears A and D is performed. If the control unit determines that the second predetermined vehicle condition is fulfilled, the control unit is configured to execute the switching from the second gear
25 shifting mode M2 to the first gear shifting mode M1.

In another example (not shown in Fig. 7b), the second predetermined vehicle condition is fulfilled when a gear shifting from one of the main gears A and D to another available main gear of the set of main gears is performed. As an example, the second predetermined vehicle condition is fulfilled when a gear shifting from the main gear D to
30 the main gear E is performed.

In yet another example embodiment, the second predetermined vehicle condition may be related to another type of condition. By way of example, the second predetermined vehicle condition may be any one of a change in vehicle inclination, change in rolling

resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof. This type of condition may be monitored, evaluated, determined and fulfilled in a similar manner as mentioned in relation to the first predetermined vehicle condition.

- 5 In another example embodiment of the method (not shown), the step of determining if the second predetermined vehicle conditions is fulfilled comprises the step of comparing a measured second vehicle condition value with a predefined threshold value relating to any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination
10 thereof.

It should also be readily appreciated that in some example embodiments, any one of the first predetermined vehicle condition and the second predetermined vehicle condition may be detected by a vehicle terrain memory function. By way of example, the vehicle terrain memory function can be configured to detect whether the vehicle is operated in a similar
15 manner as in a previous occasion, e.g. at a previous position, with a similar vehicle inclination sequence or with a similar rolling resistance sequence. If the terrain memory function detects this type of similar behavior, the control unit 600 can evaluate and determine whether the transmission should be operated in a similar manner as in the previous occasion.

- 20 Optionally, the method may include an additional two-step gear shift when the transmission is in the second gear shifting mode M2. That is, the method may include a preceding two-step gear shift in the second gear shifting mode M2 prior to the two-step gear shift from the fourth forward gear (gear 4) to the intermediate auxiliary gear 2.5*. By referring again to Fig. 7b, it can be seen that the method includes the following steps
25 starting from when the transmission is in the sixth forward gear (gear 6); switching from the first gear shifting mode to the second gear shifting mode when the first predetermined vehicle condition is fulfilled; performing a two-step gear shift from the sixth forward gear (gear 6) to the fourth forward gear (gear 4), while excluding the fifth forward gear (gear 5), which is now unavailable; performing another two-step gear shift from the fourth forward
30 gear (gear 4) to the intermediate auxiliary gear 2.5*, while excluding the unavailable third forward gear (gear 3). That is, in this example, the preceding two-step gear shift corresponds to the two-step gear shift to the main gear D from the main gear F, while excluding the main gear E, which is unavailable in the second gear shifting mode M2.

In a general summary of the execution of the method on the basis of a transmission as described in relation to the examples in Figs. 2-6, it should be readily appreciated that in all example embodiments of the method, the plurality of the shift elements comprises a number of locking elements 138, 140, 142 and a number of connecting elements 144, 146, 148, 150. In addition, each one of the main gears A, B, C and D, and the intermediate auxiliary gear I is obtainable by positioning one and the same locking element 142 in an engaged state, see Table 7. As may be noted from the Table 7, also the main gear F is here obtainable by positioning one and the same locking element 142 in the engaged state. In this context, the main gear F refers on a general basis to a main gear arranged two consecutive gear stages from the main gear D in the set of main gears, as indicated in Table 7 above. Further, each one of the main gears A, D, and the intermediate auxiliary gear I is obtainable by positioning one and the same connecting element 148 in an engaged state, see Table 7. As may be noted from Table 7, also the main gear F is here obtainable by positioning one and the same connecting element 148 in the engaged state. Moreover, each one of the main gears A, B, C and D, and the intermediate auxiliary gear I is in this example obtainable by positioning one and the same connecting element 144 in a disengaged state, see Table 7. Also, in this example, each one of the main gears A, B, C and D, and the intermediate auxiliary gear I are obtainable by positioning one and the same locking element 140 in a disengaged state. Furthermore, in this example, the locking element 140 is positioned in the disengaged state for each one of the main gears E and F, and all other forward gears, as can be seen in Table 7.

Further, as mentioned above in relation to the Figs. 2-6, the gears are typically obtained by positioning some of the shift elements in an engaged state and some of the shift elements in a disengaged state. Thus, in the examples as described above in relation to the Figs. 7a-8b, for each one of the main gears A, B, C and D and the intermediate auxiliary gear I, the method here comprises the step of positioning three of the shift elements in an engaged state. In addition, the method typically comprises the step of positioning four of the shift elements in a disengaged state. It should be noted that these steps also generally relate to the other main gears of the set of the main gears, i.e. the main gears A-F are obtainable by positioning three of the shift elements in an engaged state and positioning four of the shift elements in a disengaged state.

In particular, as may be gleaned from Table 7 above, the method is typically configured to position the third locking element 142, and the first 146 and third 148 connecting elements in the engaged state when engaging the intermediate auxiliary gear I. Analogously, the

method is typically configured to position the first 138 and the third 142 locking elements, and the third connecting element 148 in the engaged state when engaging main gear A; position the first 138 and the third 142 locking elements, and the fourth connecting element 150 in the engaged state when engaging main gear B; position the third locking
5 element 142, and the first 146 and fourth 150 connecting elements in the engaged state when engaging main gear C; and position the third locking element 142, and the third 148 and fourth 150 connecting elements in the engaged state when engaging main gear D.

In view of the above disclosure of various example embodiments of the method, there is provided a method that can be implemented in several different types of transmissions,
10 e.g. in any one of the examples of transmissions described in relation to the Figs. 2-6, but also in other types of transmissions for vehicles. Typically, although not strictly necessary, the transmission may comprise the first 102, the second 104, the third 106, and the fourth 108 planetary gear set, each one comprising a sun gear, a planet carrier and a ring gear, wherein the transmission arrangement further comprises the transmission housing 160,
15 the input shaft 136 and the output shaft 112, and wherein: the planet carrier 102P of the first planetary gear set 102 and the output shaft 112 are operatively connected to each other; the ring gear 102R of the first planetary gear set 102 and the planet carrier 104P of the second planetary gear set 104 are operatively connected to each other; the sun gear 102S of the first planetary gear set 102 and the sun gear 104S of the second planetary
20 gear set 104 are operatively connected to each other; the ring gear 104R of the second planetary gear set 104 and the planet carrier 106P of the third planetary gear set 106 are operatively connected to each other; and two of the sun gear 108S, the planet carrier 108P and the ring gear 108R of the fourth planetary gear set 108 are each operatively connected to a respective one of the input shaft 136, the sun gear 106S, the planet carrier
25 106P and the ring gear 106R of the third planetary gear set 106. However, a transmission may be provided in another type of configuration and may include a different number of elements and components. Thus, it should be readily appreciated that the example embodiments of the method as described herein may likewise be implemented in other types of transmissions.

30 Further, as mentioned above, the vehicle typically comprises the control unit 600. The control unit 600 is here configured to control the two-step gear shift in the transmission 100, 200, 300, 400, 500, as described above in relation to the Figs. 2-6. In this context, the control unit 600 is configured to perform the steps of the method as described above in relation to the Figs. 7a, 7b, 8a and 8b. In brief, this means that the control unit 600 is at

least configured to, when selecting one of the main gears A and D of the adjacent surrounding pair of main gears, evaluate a switching from the first gear shifting mode M1 to the second gear shifting mode M2 by determining if the first predetermined vehicle condition is fulfilled, and further to switch from the first gear shifting mode M1 to the
5 second gear shifting mode M2 if the first predetermined vehicle condition is fulfilled, and also to perform the two-step gear shift from one of the main gears A and D of the adjacent surrounding pair of main gears to the intermediate auxiliary gear I, while excluding one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of the one of the main gears A and D and the gear ratio of
10 the intermediate auxiliary gear I. The other steps of the method may be performed by the control unit in a similar manner.

The vehicle 201 thus further comprises the control unit 600 for controlling the vehicle 201 and in particular for controlling the transmission such that the transmission can perform the steps of the method according to various embodiments of the invention. The control
15 unit 600 may include a microprocessor, microcontroller, programmable digital signal processor or another programmable device. The control unit 600 may also, or instead, include an application specific integrated circuit, a programmable gate array or programmable array logic, a programmable logic device, or a digital signal processor. Where the control unit 600 includes a programmable device such as the microprocessor,
20 microcontroller or programmable digital signal processor mentioned above, the processor may further include computer executable code that controls operation of the programmable device. Moreover, the control unit 600 may be embodied by one or more physical control units, where each control unit may be either a general purpose control unit or a dedicated control unit for performing a specific function. As such, the vehicle thus
25 comprises the prime mover, the transmission and the control unit.

It should also be appreciated that the control unit may include a computer program comprising program code means for performing the steps of the method according to various embodiments of the invention when the program is run on a computer. Further, the control unit may include a computer readable medium carrying a computer program
30 comprising program means for performing the steps of the method according to various embodiments of the invention when the program means is run on a computer.

It is to be understood that the present invention is not limited to the embodiments described above and illustrated in the drawings; rather, the skilled person will recognize that many changes and modifications may be made within the scope of the appended

claims. For example, although the present invention has mainly been described in relation to an articulated hauler, the invention should be understood to be equally applicable for any type of vehicle. In addition, while the method of the present invention has mainly been described in relation to down-shifting, it should be noted that the method can used to
5 implement shifting strategies according to the example embodiments in both directions, i.e. up-shifting and down-shifting. Thus, the method of the present invention may likewise be used when performing an up-shift, e.g. from one of the main gears of the transmission to the intermediate auxiliary gear of the transmission.

CLAIMS

1. A method for controlling a two-step gear shift in a transmission (100, 200, 300, 400, 500), said transmission comprising a plurality of shift elements (138, 140, 142, 144, 146, 148, 150) being engageable in combinations to obtain a plurality of gear stages to obtain
5 a set of main gears, defining at least a main gear A, main gear B, main gear C and main gear D, each one of the main gears having a corresponding gear ratio, said main gears B and C further defining a pair of consecutive main gears, and said main gears A and D defining a pair of adjacent surrounding main gears, and further to obtain at least one auxiliary gear I positioned intermediate said pair of consecutive main gears B and C, said
10 intermediate auxiliary gear I having a gear ratio being intermediate the gear ratios of said pair of consecutive main gears B and C,

characterized by the steps of:

- when selecting one of said main gears A and D of the adjacent surrounding pair of main gears, evaluating a switching from a first gear shifting mode (M1) to a second gear shifting
15 mode (M2) by determining if a first predetermined vehicle condition is fulfilled, said first gear shifting mode (M1) corresponding to a mode in which all main gears of the set of main gears are available, while said intermediate auxiliary gear I is unavailable, and said second gear shifting mode (M2) corresponding to a mode in which said intermediate auxiliary gear I is available, while at least said pair of consecutive main gears B and C are
20 unavailable,

- if said first predetermined vehicle condition is fulfilled, switching from said first gear shifting mode (M1) to said second gear shifting mode (M2), and

- performing a two-step gear shift from one of said main gears A and D of said adjacent surrounding pair of main gears to said intermediate auxiliary gear I, while excluding one of
25 the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of said one of said main gears A and D and the gear ratio of the intermediate auxiliary gear I.

2. The method according to claim 1, **characterized by** the step of:

- performing an additional two-step gear shift from said intermediate auxiliary gear I to the
30 other main gear A and D of the adjacent surrounding pair of main gears, while excluding the other one of the unavailable main gears of the pair of consecutive main gears B and C

having a gear ratio in between the gear ratio of the intermediate auxiliary gear I and the gear ratio of said other main gear of the adjacent surrounding pair of main gears A and D, or

performing a two-step gear shift from said intermediate auxiliary gear I for returning to
5 said one of said adjacent surrounding pair of main gears A and D, while excluding said one of the unavailable main gears B and C of the pair of consecutive main gears having a gear ratio in between the gear ratio of said one of said adjacent surrounding pair of main gears A and D and the gear ratio of the intermediate auxiliary gear I.

3. The method according to claims 1-2, **characterized by** said first predetermined vehicle
10 condition being any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

4. The method according to claim 3, **characterized by** determining if said first predetermined vehicle condition is fulfilled comprising the step of comparing a measured
15 first vehicle condition value with a predefined threshold value relating to any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

5. The method according to claims 1-2, **characterized by** said first predetermined vehicle condition being fulfilled by a previous gear shifting sequence, said previous gear shifting
20 sequence including a two-step gear shift to any one of said main gears A and D of the adjacent surrounding pair of main gears.

6. The method according to claim 2, **characterized by** the step of:

- switching from said second gear shifting mode (M2) to said first gear shifting mode (M1) when a second predetermined vehicle condition is fulfilled.

25 7. The method according to claim 6, **characterized by** said second predetermined vehicle condition being fulfilled when a gear shifting from said intermediate auxiliary gear I to one of the main gears A and D is performed, or when a gear shifting from one of the main gears A and D to another available main gear of the set of main gears is performed.

8. The method according to claim 6, **characterized by** said second predetermined vehicle
30 condition being any one of a change in vehicle inclination, change in rolling resistance,

change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

9. The method according to claim 8, **characterized by** determining if said second predetermined vehicle conditions is fulfilled comprising the step of comparing a measured
5 second vehicle condition value with a predefined threshold value relating to any one of a change in vehicle inclination, change in rolling resistance, change in vehicle speed, acceleration, deceleration, change in accelerator pedal position, or a combination thereof.

10. The method according to claim 6, **characterized by** any one of said first predetermined vehicle condition and said second predetermined vehicle condition being
10 detected by a vehicle terrain memory function.

11. The method according to any one of the preceding claims, **characterized by** said shifting from one of said main gears A and D of said adjacent surrounding pair of main gears to said intermediate auxiliary gear I being a single shift.

12. The method according to any one of the preceding claims, **characterized by** having
15 said plurality of shift elements comprising a number of locking elements (138, 140, 142) and a number of connecting elements (144, 146, 148, 150).

13. The method according to claim 12, **characterized by** each one of the main gears A, B, C and D, and the intermediate auxiliary gear I being obtainable by positioning one and the same locking element (142) in an engaged state.

20 14. The method according to any one of the preceding claims 12-13, **characterized by** each one of the main gears A and D, and the intermediate auxiliary gear I being obtainable by positioning one and the same connecting element (148) in an engaged state.

15. The method according to any one of the preceding claims 12-14, **characterized by**
25 each one of the main gears A, B, C and D, and the intermediate auxiliary gear I being obtainable by positioning one and the same connecting element (144) in a disengaged state.

16. The method according to any one of the preceding claims 12-15, **characterized by** having seven shift elements comprising three locking elements (138, 140, 142) and four
30 connecting elements (144, 146, 148, 150).

17. The method according to claim 16, wherein for each one of the main gears A, B, C and D and the intermediate auxiliary gear I, the method is **characterized by** comprising the steps of:

- positioning three of the shift elements in an engaged state, and

5 - positioning four of the shift elements in a disengaged state.

18. The method according to claim 17, **characterized by** the further step of:

- positioning the third locking element (142), and the first (146) and third (148) connecting elements in an engaged state when engaging said intermediate auxiliary gear I.

19. The method according to any one of the preceding claims 17-18, **characterized by**
10 the steps of:

- positioning the first (138) and the third (142) locking elements, and the third connecting element (148) in an engaged state when engaging main gear A;

- positioning the first (138) and the third (142) locking elements, and the fourth connecting element (150) in an engaged state when engaging main gear B;

15 - positioning the third locking element (142), and the first (146) and fourth (150) connecting elements in an engaged state when engaging main gear C;

- positioning the third locking element (142), and the third (148) and fourth (150) connecting elements in an engaged state when engaging main gear D.

20. The method according to any one of the preceding claims, **characterized by** said set
20 of main gears comprising nine forward gears and three reverse gears, and said one intermediate auxiliary gear I is an intermediate auxiliary forward gear I.

21. The method according to claim 20, **characterized by** said pair of consecutive main gears B and C being the second and third forward gears, respectively, said pair of adjacent surrounding main gears A and D being the first and fourth forward gears,
25 respectively, and said intermediate auxiliary gear I being an intermediate auxiliary gear I having a gear ratio intermediate the gear ratios of the second and third forward gears.

22. The method according to any one of the preceding claims, **characterized by** the transmission comprising a first (102), a second (104), a third (106), and a fourth (108) planetary gear set comprising a sun gear, a planet carrier and a ring gear, respectively,

wherein said transmission arrangement further comprises a transmission housing (160), an input shaft (136) and an output shaft (112), wherein:

- the planet carrier (102P) of the first planetary gear set (102) and the output shaft (112) are operatively connected to each other;
- 5 - the ring gear (102R) of the first planetary gear set (102) and the planet carrier (104P) of the second planetary gear set (104) are operatively connected to each other;
- the sun gear (102S) of the first planetary gear set (102) and the sun gear (104S) of the second planetary gear set (104) are operatively connected to each other;
- the ring gear (104R) of the second planetary gear set (104) and the planet carrier (106P)
- 10 of the third planetary gear set (106) are operatively connected to each other; and
- two of the sun gear (108S), the planet carrier (108P) and the ring gear (108R) of the fourth planetary gear set (108) are each operatively connected to a respective one of the input shaft (136), the sun gear (106S), the planet carrier (106P) and the ring gear (106R) of the third planetary gear set (106).
- 15 23. A control unit (600) for controlling a two-step gear shift in a transmission (100, 200, 300, 400, 500), said transmission comprising a plurality of shift elements (138, 140, 142, 144, 146, 148, 150) being engageable in combinations to obtain a plurality of gear stages to obtain a set of main gears, defining at least a main gear A, main gear B, main gear C and main gear D, each one of the main gears having a corresponding gear ratio, said
- 20 main gears B and C further defining a pair of consecutive main gears, and said main gears A and D defining a pair of adjacent surrounding main gears, and further to obtain at least one auxiliary gear I positioned intermediate said pair of consecutive main gears B and C, said intermediate auxiliary gear I having a gear ratio being intermediate the gear ratios of said pair of consecutive main gears B and C,
- 25 **characterized in that** the control unit (600) is configured to:
 - when selecting one of said main gears A and D of the adjacent surrounding pair of main gears, evaluate a switching from a first gear shifting mode (M1) to a second gear shifting mode (M2) by determining if a first predetermined vehicle condition is fulfilled, said first gear shifting mode (M1) corresponding to a mode in which all main gears of the set of
 - 30 main gears are available, while said intermediate auxiliary gear I is unavailable, and said second gear shifting mode (M2) corresponding to a mode in which said intermediate

auxiliary gear I is available, while at least said pair of consecutive main gears B and C are unavailable,

- if said first predetermined vehicle condition is fulfilled, switch from said first gear shifting mode (M1) to said second gear shifting mode (M2), and

5 - perform a two-step gear shift from one of said main gears A and D of said adjacent surrounding pair of main gears to said intermediate auxiliary gear I, while excluding one of the unavailable main gears of the pair of consecutive main gears B and C having a gear ratio in between the gear ratio of said one of said main gears A and D and the gear ratio of the intermediate auxiliary gear I.

10 24. A vehicle comprising a prime mover, a transmission and a control unit according to claim 23.

25. A computer program comprising program code means for performing the steps of any one of claims 1 – 22 when said program is run on a computer.

26. A computer readable medium carrying a computer program comprising program
15 means for performing the steps of any one of claims 1 – 22 when said program means is run on a computer.

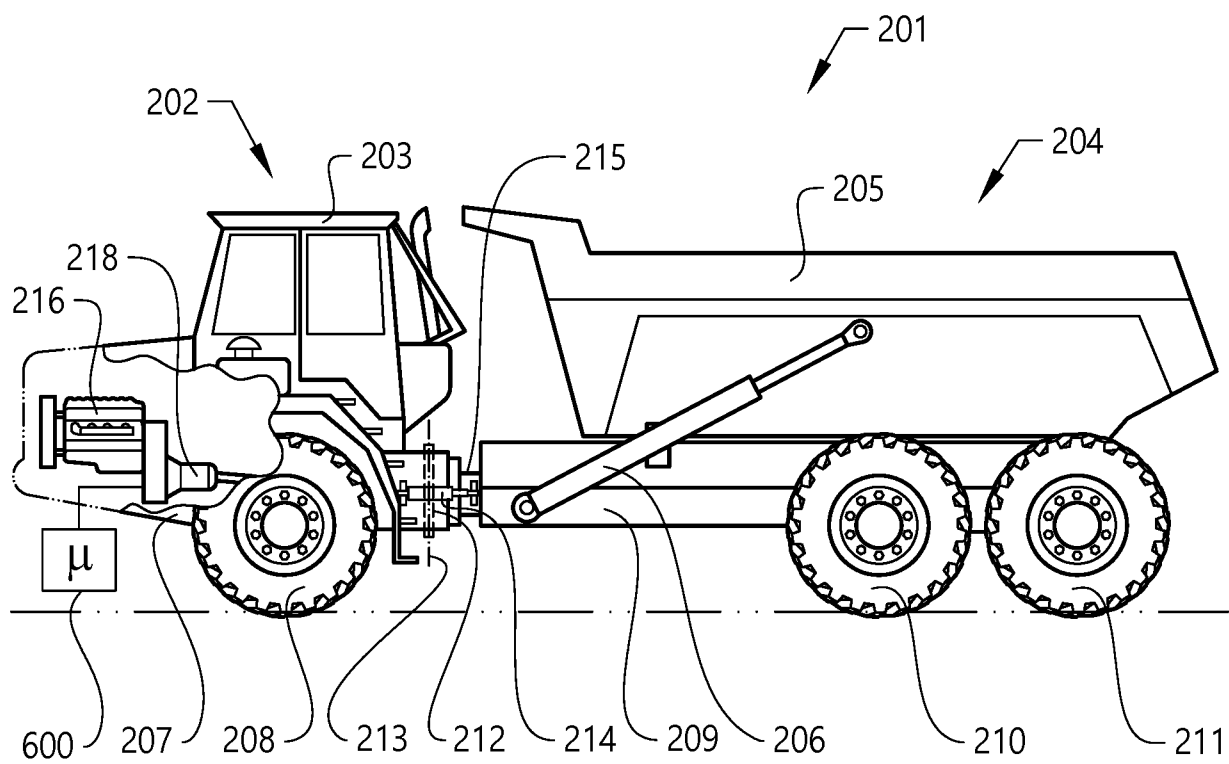


FIG. 1

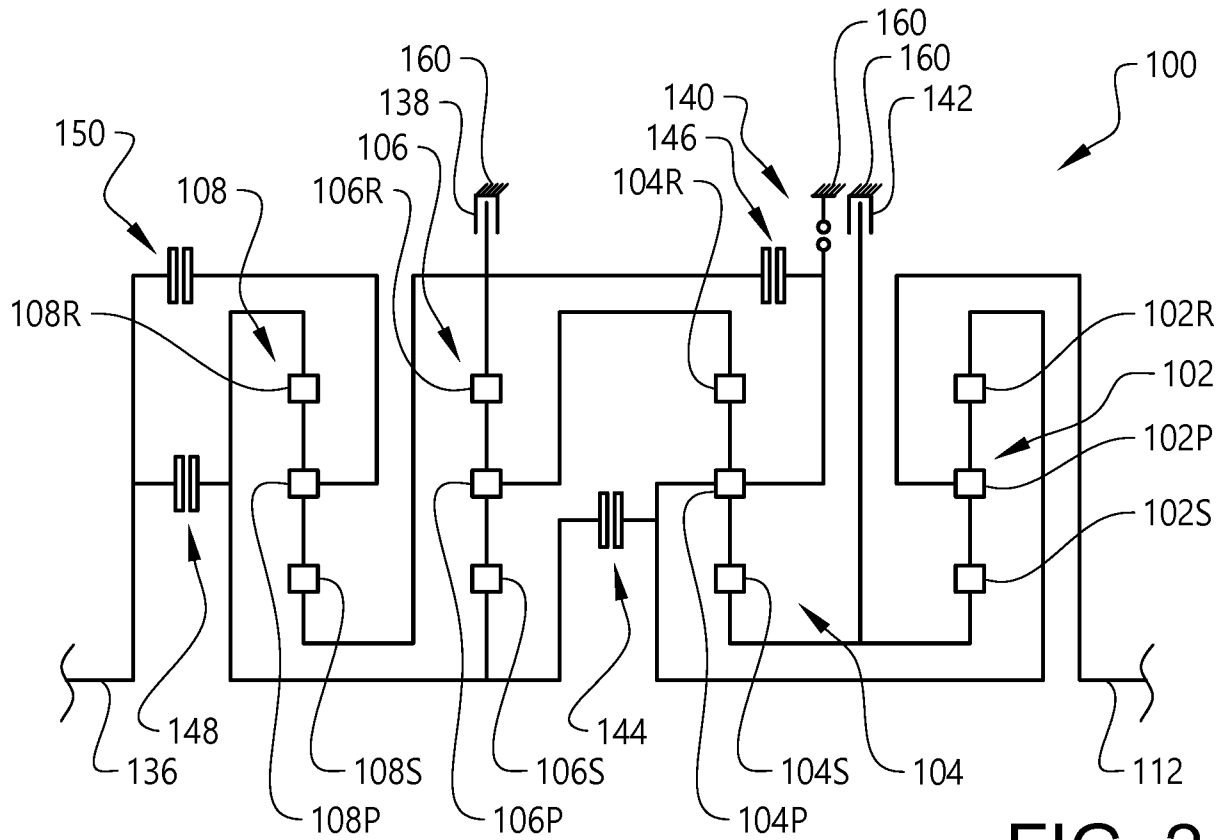


FIG. 2

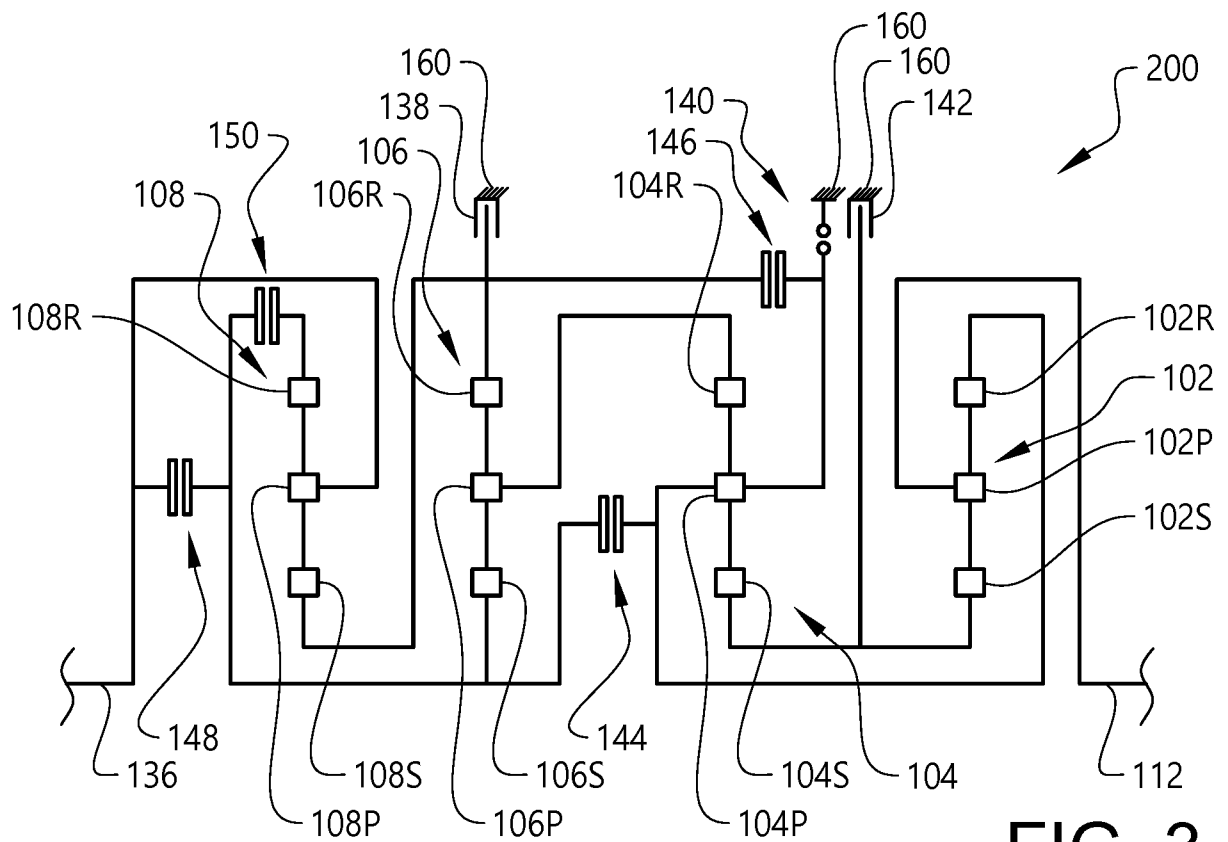


FIG. 3

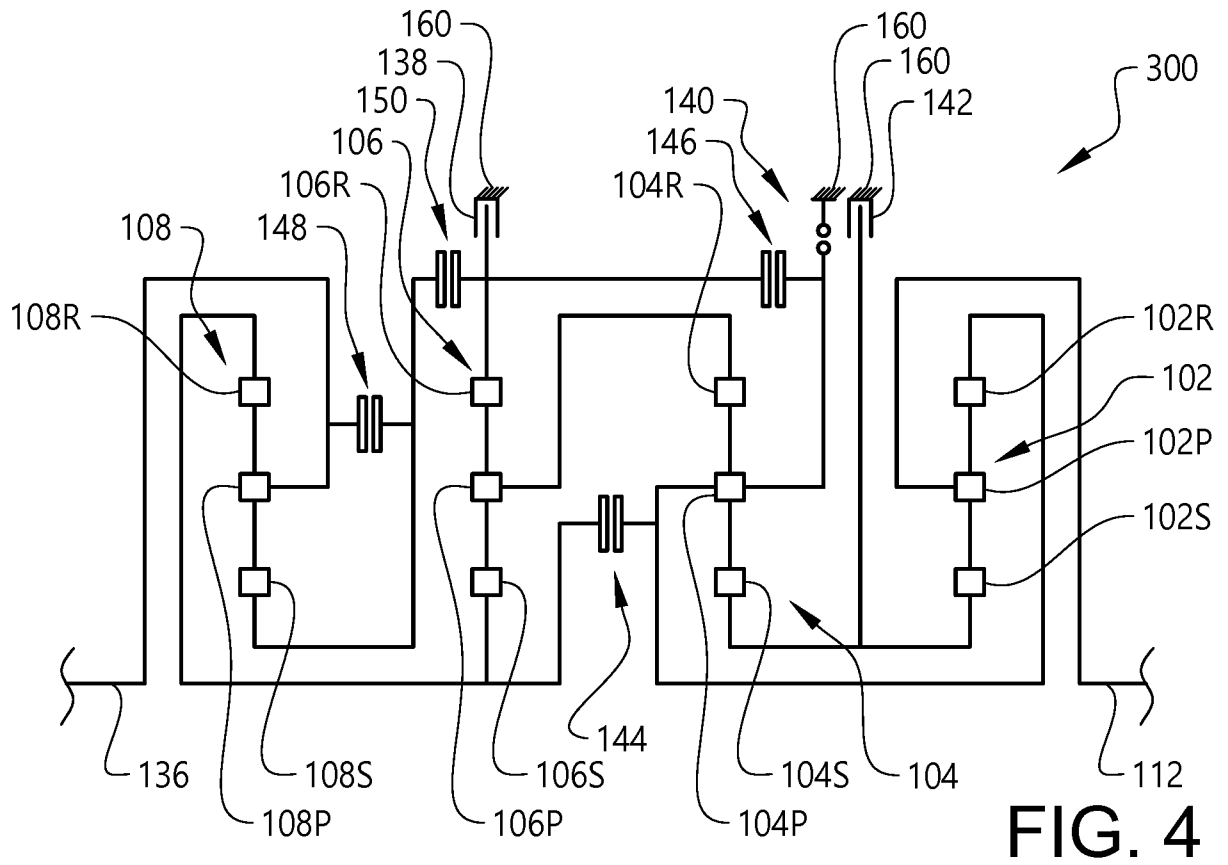


FIG. 4

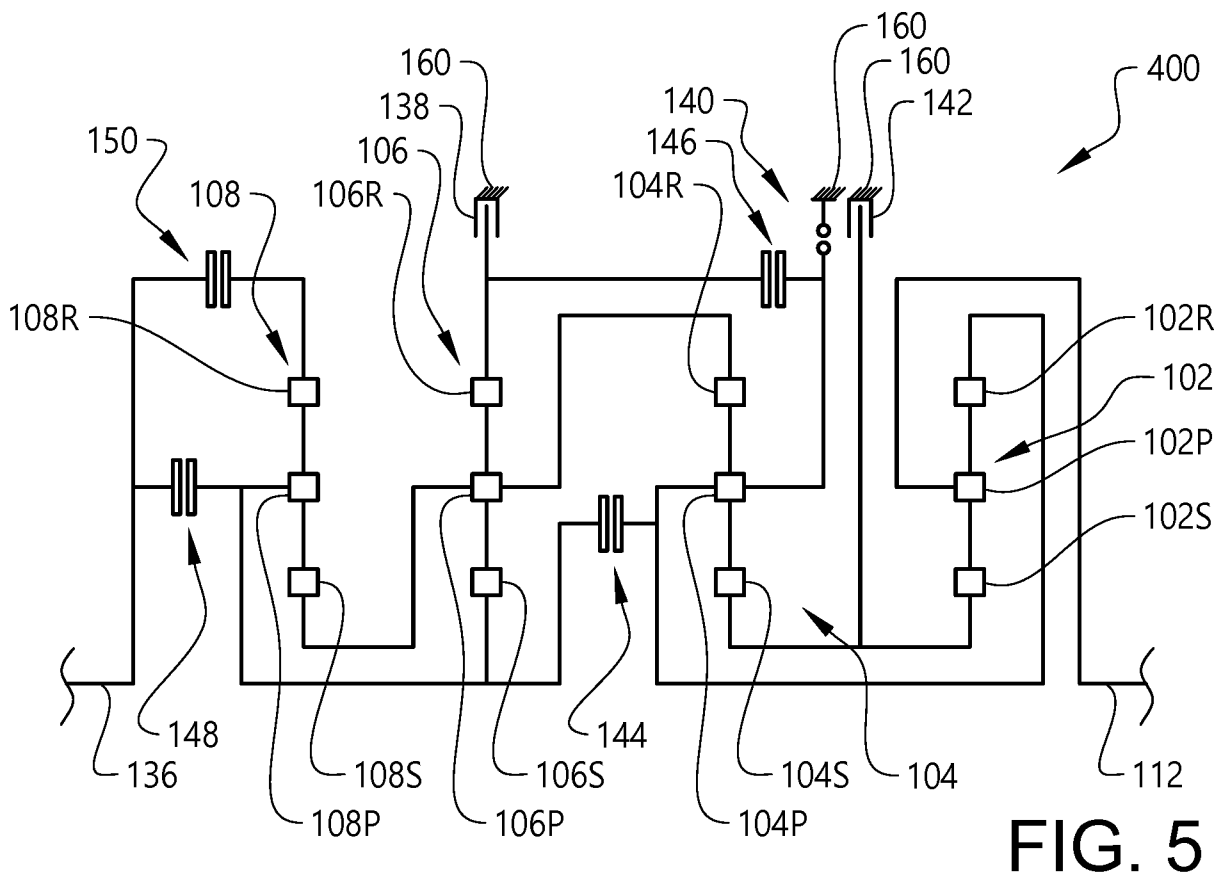


FIG. 5

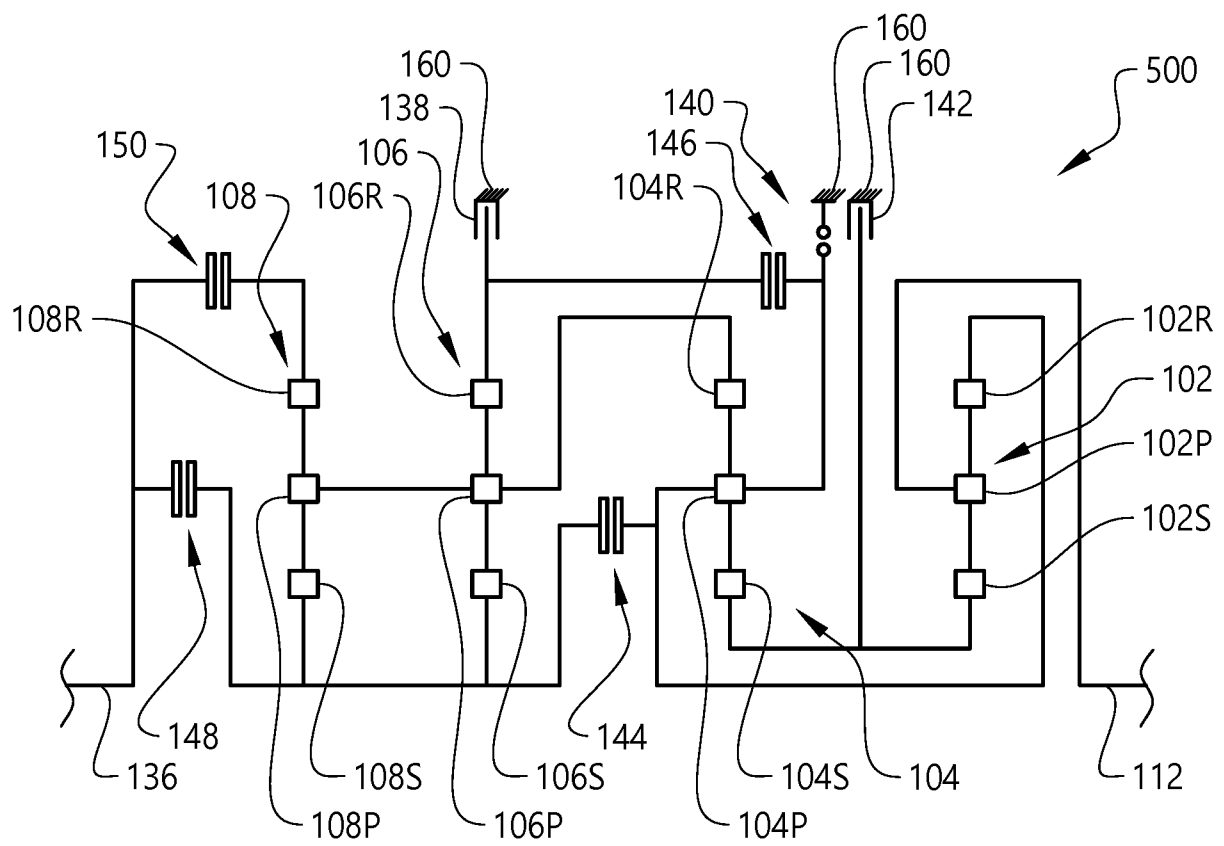


FIG. 6

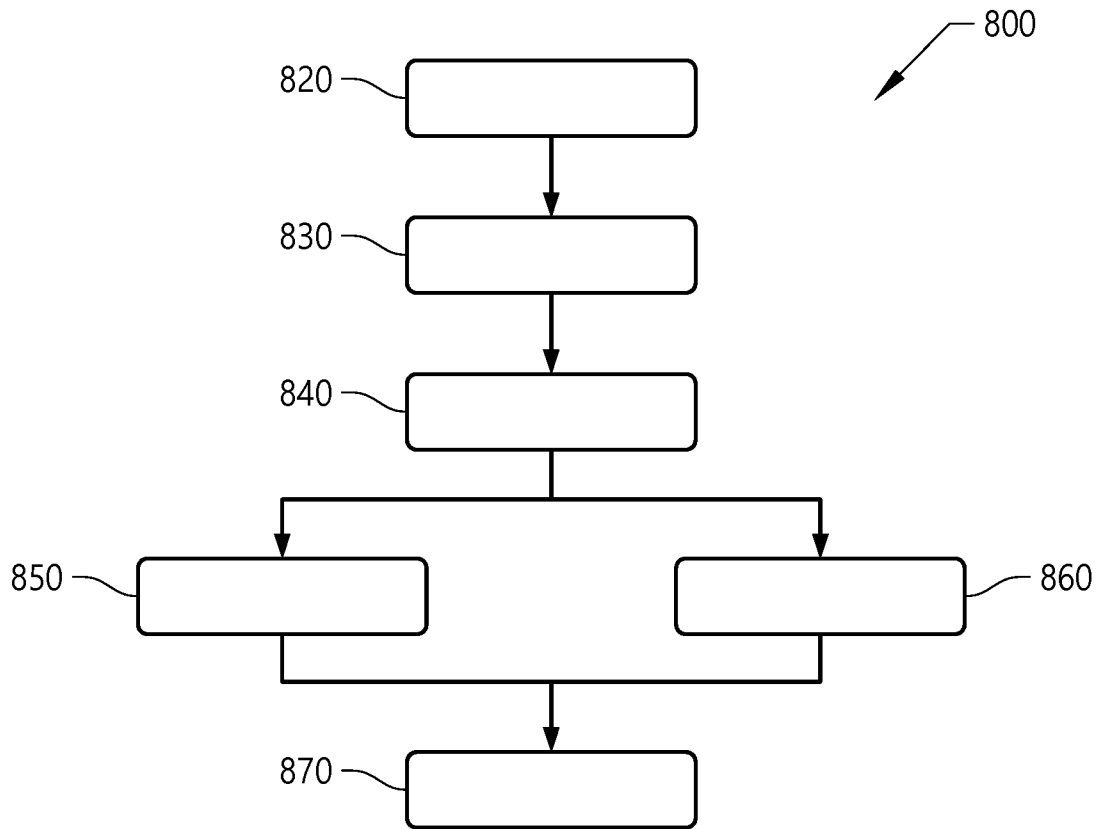


FIG. 7a

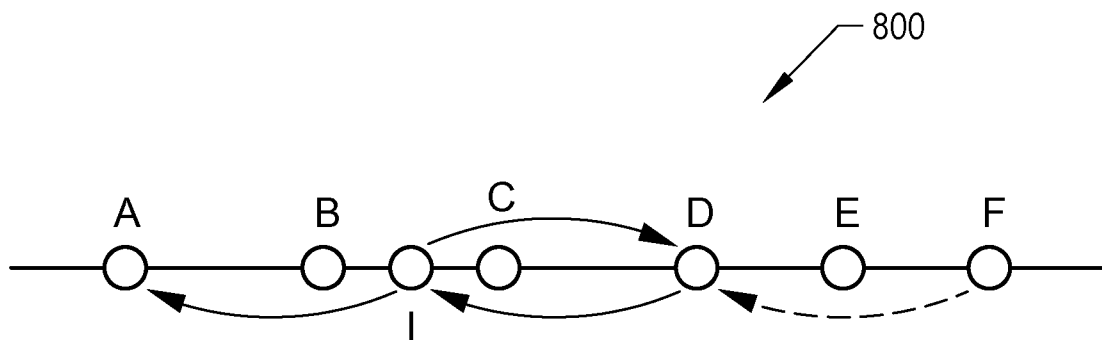


FIG. 7b

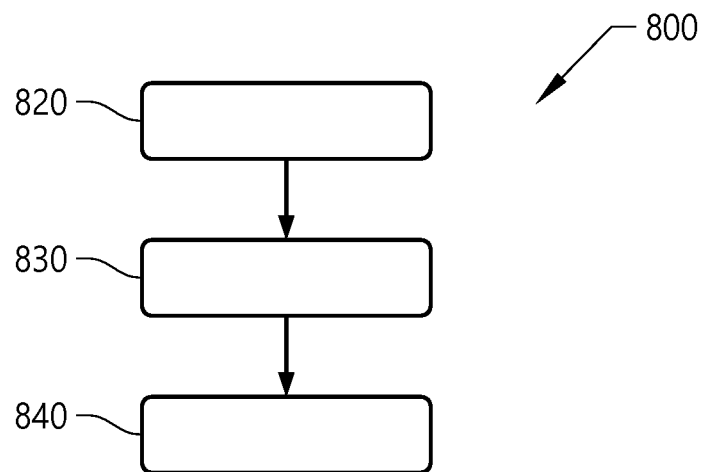


FIG. 8a

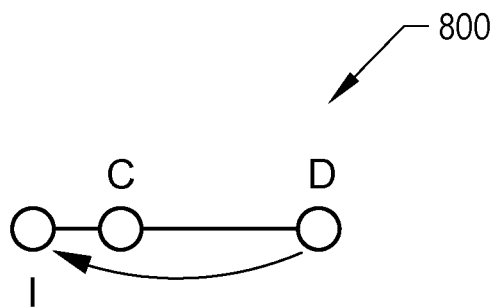


FIG. 8b

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/080240

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16H61/04 F16H61/02 F16H3/66
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)

F16H

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	EP 1 624 231 A2 (DAIMLER CHRYSLER CORP [US]) 8 February 2006 (2006-02-08)	1,3-12, 14,16, 23-26
Y	abstract; figures 1-3	13-22
A	paragraphs [0004] - [0007], [0017] - [0027]	2
Y	----- WO 2017/010919 A1 (VOLVO CONSTR EQUIP AB [SE]) 19 January 2017 (2017-01-19) cited in the application abstract; figures 1,2; tables 6,7 page 18, line 11 - page 20, line 18 ----- -/-	13-22



Further documents are listed in the continuation of Box C.



See patent family annex.

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

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"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

10 July 2018

Date of mailing of the international search report

18/07/2018

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Daïeff, Bertrand

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/080240

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 742 733 A (SCHREINER FRIEDRICH [DE]) 10 May 1988 (1988-05-10)	1-4,6,8, 9,11,12, 15,16, 23-26
A	abstract; figures 1-3,6 column 3, line 37 - column 5, line 32 -----	5,7,10
A	AT 516 023 B1 (AVL LIST GMBH [AT]) 15 February 2016 (2016-02-15) abstract; figure 1 paragraphs [0006] - [0010], [0020] - [0022] -----	1-26

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2017/080240

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