

(51) International Patent Classification:
F16H 61/688 (2006.01)(21) International Application Number:
PCT/EP2009/008343(22) International Filing Date:
24 November 2009 (24.11.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
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(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM,

AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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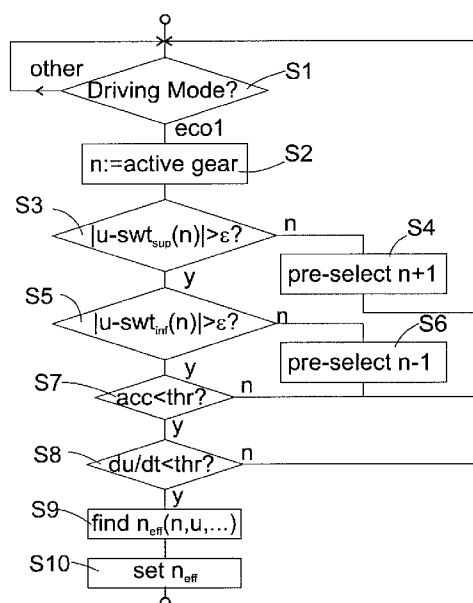
— of inventorship (Rule 4.17(iv))

Published:

— with international search report (Art. 21(3))

(54) Title: METHOD AND APPARATUS FOR CONTROLLING A DOUBLE-CLUTCH TRANSMISSION

Fig. 2



(57) Abstract: A method is disclosed for controlling a double-clutch transmission (2) having two transmission sub-units (15, 17, 18, 22, 23, 29, 30; 16, 19, 20, 24, 31, 32) capable of assuming a plurality of shifting states, wherein one of the sub-units (15, 17, 18, 22, 23, 29, 30; 16, 19, 20, 24, 31, 32) has shifting states associated to a first set of gears and the other sub-unit has shifting states associated to a second set of gears, and both sub-units are capable of assuming a shifting state associated to a given gear of their associated set at the same time. The method comprises the steps of a) detecting whether the transmission is in a steady state of operation (S1, S3, S5, S7, S8) in which a first one of said sub-units is in a shifting state associated to a gear and is bearing a load, whereas the second sub-unit is idle; b) if a steady state is detected, determining among the shifting states of the idle sub-unit, depending on at least the associated gear of the load-bearing sub-unit, the shifting state in which losses are smallest (S9); c) placing the idle sub-unit in the determined shifting state (S10).

5 Method and Apparatus for Controlling a Double-Clutch Transmission

10	D e s c r i p t i o n
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The present invention relates to a method for controlling a double-clutch transmission for a motor vehicle, to a controller for carrying out the method and to computer program products embodying the method.

A double-clutch transmission, as shown e.g. in Fig. 3 of this application, conventionally has two coaxial input shafts, each of which is associated to a clutch member of the double-clutch. At a given instant, usually only one of the two clutch members is closed, so that its associated input shaft is under load. Each input shaft carries one or more drive gearwheels which mesh with associated idler gearwheels on one or more layshafts. The idler gearwheels can be selectively locked to the layshafts carrying them. An active gear of the double-clutch transmission is determined by a locked idler gearwheel which meshes with a drive gearwheel of the currently load-bearing input shaft. While one gear is active, another gear can be pre-selected by locking an idler gearwheel which meshes with a drive gearwheel of the currently unloaded input shaft. If a gear is pre-selected, it can be made the active gear quickly and without interrupting the torque flow through the transmission by opening the currently closed clutch member and closing the other.

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For selecting the active gear, an automatic transmission controller conventionally monitors the state of motion of the vehicle, in particular the speed of the vehicle and/or the speed of the input shafts of the transmission and/or the torque load. Based on these parameters, it is possible to tell whether a shifting of gears might become necessary in the near future, and whether it will be up- or downshifting. By pre-selecting a gear which is higher or lower than the active gear by 1, the duration of the shifting process can be minimized.

Transmissions inevitably have an efficiency of less than 100% due to friction losses between meshing gearwheels and in bearings of rotating parts. These losses are the higher, the greater the number of meshing and rotating parts is.

The object of the present invention is to minimize such losses in a double clutch transmission.

This object is achieved by a method for controlling a double-clutch transmission, the transmission having two sub-units capable of assuming a plurality of shifting states, wherein one of the sub-units has shifting states associated to a first set of gears and the other sub-unit has shifting states associated to a second set of gears, and both sub-units are capable of assuming a shifting state associated to a given gear of their associated set at the same time, the method comprising the steps of

a) detecting whether the transmission is in a steady state of operation in which a first one of said sub-units is in a shifting state associated to a gear and is bearing a load, whereas the second sub-unit is idle;

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b) if a steady state is detected,
determining, depending on at least the shifting state of
the load-bearing sub-unit, a shifting state of the idle
sub-unit in which losses are smallest;

5 c) placing the idle sub-unit in the
determined shifting state.

The invention is based on the insight that in
conventional double clutch transmissions, if a gear is
10 pre-selected at the idle sub-unit, it is usually higher
or lower than the currently active gear at the load-
bearing sub-unit by 1, because the pre-selected gear is
likely to become active when gears are shifted. However,
it is usually absolutely feasible from a technical point
15 of view to pre-select any other gear from the set of
gears associated to the idle sub-unit. I.e. a higher gear
than the active one might be pre-selected although the
state of motion of the vehicle would rather suggest
downshifting, or vice versa. Moreover, a gear might be
20 pre-selected which differs by more than 1 from the
presently active gear. Generally, there is a plurality of
gears available for pre-selection, and the invention
suggests to pre-select among these the gear which
minimizes friction losses, at least as long as the state
25 of motion of the vehicle or other criteria do not suggest
that shifting is imminent.

It should be noted that the shifting states of
each sub-unit may comprise not only specific gears, but
30 also a neutral state.

Preferably, one set of gears comprises odd
gears and the other set of gears even ones.

35 It is conceivable that the shifting state in
which friction losses are smallest depends not only on

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the active gear and the design of the transmission, but also on its state of motion. Therefore it may be preferable to determine the shifting state of the idle sub-unit in step b) depending not only on the active gear, but also on the speed of a drive shaft of the transmission.

One condition for detecting a steady state of operation may be that a mode selector is set so as to allow detection of the steady state. In other words, if a driver wishes to avoid a possible prolongation of the shifting process which might be caused by the need to de-select the pre-selected low-loss gear, he can disable execution of the method using the mode selector.

15

Another condition for detecting a steady state of operation may be that the clutch member associated to the load-bearing sub-unit is closed. If the active gear of the transmission is controlled manually by the driver, it cannot be predicted reliably from the state of motion of the vehicle whether shifting is likely to occur or not, but the fact that the clutch member of the load-bearing input shaft is being opened is a reliable indicia that a shifting process is beginning.

25

Other useful criteria for detecting a steady state are that the rate of change of the speed of the drive shaft is below a predetermined threshold, or that the rate of change of the position of an accelerator pedal is below a predetermined threshold.

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Further, if at least one shifting threshold speed of the drive shaft is associated to each gear of the set associated to the load-bearing sub-unit, a steady state of operation may be detected if the difference between the speed of the drive shaft and each shifting

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threshold of the currently active gear is above a predetermined threshold.

5 The optimum shifting state of the idle sub-unit for any driving condition may conveniently be determined by consulting a lookup table. Such a lookup table may be prepared by a manufacturer of the transmission or of the motor vehicle in which the gear box is used, based on experimental data.

10

 The invention may also be embodied in a controller for a vehicle transmission adapted to carry out the method as described above.

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 In such a controller, a mode selector is advantageously provided for choosing between at least first economic and sport driving modes, which modes use different algorithms for automatically selecting the active gear of the transmission depending on driving conditions, e.g. on drive shaft speed and load, and execution of the method is enabled in the first economic mode and is disabled in the sport mode. Use of the method is preferably limited to the first economic mode since the need to de-select before shifting a pre-selected gear which must not become active may lead to somewhat longer shifting times. This will not be critical when driving in a calm, economic way, but it may be fastidious in a sport mode where fast shifting is an asset.

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 It is further conceivable to implement a second economic mode which uses the same algorithm for selecting the active gear as the first economic mode, and in which execution of the method is disabled.

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For reasons of fuel economy, it is preferred that the first economic mode is automatically pre-selected upon start-up.

5 The invention may further be embodied in a computer program product comprising program code means for enabling a computer, when carried out on it, to execute the above described method, or in a recording medium in which the computer program product is recorded
10 in machine readable form.

 Further features and advantages of the invention will become apparent from the subsequent description of embodiments thereof referring to the
15 appended drawings.

 Fig. 1 is a schematic block diagram of the traction system of a motor vehicle embodying the present invention;
20

 Fig 2 is a flowchart of the method of the invention;

 Fig. 3 depicts a double-clutch transmission to which the present invention is applicable;
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 Fig. 4 is a schematic representation of a lookup table used for controlling the transmission of Fig. 3;
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 Fig. 5 is a diagram of a second double-clutch transmission;

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Fig. 6 is a schematic representation of a lookup table used for controlling the transmission of Fig. 5.

5 Fig. 1 is a block diagram of the traction system of a motor vehicle. The system comprises a combustion engine 1, a double-clutch transmission 2 connected to the combustion engine by a drive shaft 3 and having an output shaft 4 connected to vehicle wheels, not
10 shown, a microprocessor-based transmission controller 5 for pre-selecting and activating gears in transmission 2 based on data from a rotation speed sensor 6 placed at drive shaft 3 and an accelerator pedal sensor 7, data of which may be provided to transmission controller 5
15 directly or in a form pre-processed by an engine controller 8.

A mode of operation of transmission controller 5 is determined by a mode selector switch 9, which may be
20 suitably placed at the vehicle dashboard.

Transmission controller 5 comprises a read-only memory 10 for storing operating software of the controller 5 and a lookup table, the contents of which
25 will be discussed below. The operating software enables transmission controller 5 to decide, based on the state of motion of the vehicle, in particular based on the vehicle speed and/or drive shaft speed and engine load, which one of the various gears of transmission 2 should
30 be active, and to shift to this gear if it is different from the presently active gear.

The method of the present invention is executed by transmission controller 5 concurrently with its
35 conventional task of deciding the active gear of

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transmission 2. A flowchart of the method is shown in Fig. 2.

In step S1, controller 5 checks the mode
5 selected by the driver at mode selector 9. Among the modes the driver can specify at mode selector 9, there is a sport mode and at least a first economic mode. Optionally, a second economic mode may be provided. In the sport mode, shifting thresholds between two
10 consecutive gears are lower than in the economy modes, and the speed at which an internal actuator of transmission 2 is driven for shifting from one gear to the other may be higher in the sport mode than in the economic mode. Only if the mode selector is found in the
15 first economic mode, the method proceeds to step S2; else the process is halted in a waiting loop.

The number n of the currently active gear is identified in step S2.

20

If gear n is not the highest gear of transmission 2, step S3 compares the current rotation speed u of drive shaft 3 to an upper shifting threshold $swt_{sup}(n)$ associated to currently active gear n . The
25 threshold $swt_{sup}(n)$ is slightly lower than a threshold at which upshifting will actually be triggered. If the difference between u and $swt_{sup}(n)$ is below a predetermined threshold ε it can be concluded that an upshifting is imminent. In that case, the process also
30 remains in the waiting loop. Optionally, the next higher gear $n+1$ may be pre-selected in step S4 in order to prepare for upshifting.

Analogously, in step S5 the rotation speed $S3$
35 is compared to a lower shifting threshold $swt_{inf}(n)$ associated to active gear n , which is slightly higher

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than a threshold at which downshifting is triggered. If the difference is smaller than a threshold ε , the process stays in the waiting loop, optionally pre-selecting a lower gear $n-1$ in step S6.

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If the rotation speed u is safely between the two switching thresholds $swt_{sup}(n)$ and $swt_{inf}(n)$, the acceleration of the vehicle or the rate of change of the position of accelerator pedal detected by sensor 7 is compared to a pre-determined threshold in step S7. In case of a strong positive or negative acceleration or of an abrupt operation of the accelerator pedal, it is likely that a gear shift will become necessary soon, so that again the process enters the waiting loop.

15

The same happens if in step S8 the rate of change of the speed of drive shaft 3 is found to be above a predetermined threshold.

20

Only if all the above decision steps have indicated that the presently active gear is likely to remain active for some time in the future, the lookup table in read-only memory 10 is consulted in step S9 in order to find the most energy-efficient shifting state for the currently idle input shaft. Depending on the design of the transmission 2, this optimum shifting state n_{eff} may depend not only from active gear n , but also from parameters such as the rotation speed u , vehicle speed or others, so that the lookup table may be multi-dimensional. The shifting state n_{eff} may be a state in which a gear associated to the idle input shaft is indeed pre-selected, or it may be a neutral state with no pre-selected gear at all. This optimum shifting state is set in step S10, so that the transmission may operate at optimum efficiency.

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Fig. 3 is a schematic overview of a double-clutch transmission. A double clutch 12 comprising clutch members 13, 14 is provided between drive shaft 3 and input shafts 15, 16 of transmission 2. By closing one or the other of clutch members 13, 14, torque can applied selectively to a respective one of input shafts 15, 16.

Input shaft 15 is hollow and carries two drive gearwheels 17, 18. Input shaft 16 extends coaxially through input shaft 15 and carries drive gearwheels 19, 20. A first layshaft 21 carries idler gearwheels 22, 23, 24 meshing with drive gearwheels 17, 18, 20, respectively, synchronizers 25, 26 and output pinion 27. Synchronizer 25 is adapted to lock either gearwheel 22 or 23 to layshaft 21; synchronizer 26 can lock idler gearwheel 24.

A second layshaft 28 carries idler gearwheels 29, 30, 31, 32, synchronizers 33, 34 and output pinion 35. Idler gearwheel 29 is coupled to drive gearwheel 17 by intermediate gearwheel 36, forming a reverse gear. The other idler gearwheels 30, 31, 32 mesh with drive gearwheels 18, 19, 20, respectively.

In the configuration shown, the two clutch members 13, 14 are open, and all synchronizers are disengaged. A first gear is set by locking idler gearwheel 22 using synchronizer 25 and closing clutch member 14, so that input shaft 15 is under load. In second gear, idler gearwheel 31 is locked, and clutch member 13 is closed. In third gear, synchronizer 25 locks idler gearwheel 23, and clutch member 14 is closed. In fourth gear, synchronizer 26 locks idler gearwheel 24, and clutch member 13 is closed. In fifth gear, idler gearwheel 30 is locked by synchronizer 33, and clutch

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member 13 is closed. In sixth gear, idler gearwheel 32 is locked, and clutch member 13 is closed.

While one of the two input shafts 15, 16 is
5 bearing load, and a gear associated to the loaded input shaft is active, the idle input shaft may assume various shifting states. E.g. if the first gear is active, input shaft 16 is idle, and it may either be in a neutral state, as shown in Fig. 3, or any even gear may be pre-
10 selected by synchronizer 26 or 34 engaging one of idler gearwheels 24, 31, 32. This is represented in the diagram of Fig. 4 by "+" symbols in the boxes associated to active first gear, the neutral state of input shaft 16 and even-numbered gears. Odd gears 3, 5 cannot be pre-
15 selected at the same time since they are associated to the same input shaft 16 as the first gear is.

Fig. 4 indicates for each active gear possible shifting states of the idle input shaft. It is a priori
20 not known which of these possible shifting states is the most energy efficient one. This can be found out experimentally using a prototype of the transmission or of the complete traction system in which the transmission is installed. In the lookup table of read-only memory 10,
25 the most energy efficient switching state is recorded for each active gear.

The shifting states of the idle input shaft which may be combined with a given active gear can vary
30 depending on the design of the transmission, as shown referring to Figs. 5 and 6. Fig. 5 is a diagram of a double-clutch transmission having a single layshaft 21. Hollow input shaft 15 carries drive gearwheels 17, 18, 41 for driving a reverse idler gearwheel 29 and forward
35 idler gearwheels 31, 42 on layshaft 21, and solid input shaft 16 carries drive gearwheels 19, 20, meshing with

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idler gearwheels 31, 32 of layshaft 21. A further drive gearwheel 43 is selectively locked to input shaft 16 by a synchronizer 44 and meshes with idler gearwheel 45 on layshaft 21. An output shaft 46 carries gearwheels 47, 48 meshing with idler gearwheels 45, 49 of layshaft 21. Idler gearwheels 45, 49 share a synchronizer 50 so that only one of them can be locked to layshaft 21 at a time.

For the first gear to be active in this transmission, clutch member 30 must be closed, and idler gearwheels 32, 45 are locked to layshaft 21. In second gear, clutch member 14 is closed and gearwheels 31, 45 are locked. In third gear, clutch member 14 is closed again, and gearwheels 31, 45 are locked. In fourth gear, clutch member 13 is closed and gearwheels 42, 45 are locked. In fifth gear, clutch member 14 is closed, drive gearwheel 43 is locked, and there is no torque flow along layshaft 21. In sixth gear, clutch member 14 is closed, gearwheel 31 is locked again, and gearwheel 49 is locked. In seventh gear, clutch member 13 is closed and gearwheels 31, 49 are locked, and in eighth gear, clutch member 14 is closed and gearwheels 42, 49 are locked.

Since gearwheels 45, 49 cannot be locked simultaneously, it is impossible to pre-select one of gears 6 to 8 while one of gears 1 to 5 is active, and vice versa. Nevertheless, if one of gears 1 to 5 is active, there are still three or four switching states from which the most energy-efficient one is pre-selected.

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L i s t o f r e f e r e n c e s i g n s

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|--------|-----------------------|--------|------------------------|
| 1. | combustion engine | 25. | synchronizer |
| 2. | transmission | 26. | synchronizer |
| 5 3. | drive shaft | 27. | output pinion |
| 4. | output shaft | 30 28. | 2nd layshaft |
| 5. | transmission control | 29. | idler gearwheel |
| 6. | rotation speed sensor | 30. | idler gearwheel |
| 7. | accelerator pedal | 31. | idler gearwheel |
| 10 | sensor | 32. | idler gearwheel |
| 8. | engine controller | 35 33. | synchronizer |
| 9. | mode selector | 34. | synchronizer |
| 10. | ROM | 35. | output pinion |
| 12. | double clutch | 36. | intermediate gearwheel |
| 15 13. | clutch member | 40 40. | gearwheel |
| 14. | clutch member | 41. | drive gearwheel |
| 15. | input shaft | 42. | idler gearwheel |
| 16. | input shaft | 43. | drive gearwheel |
| 17. | drive gearwheel | 44. | synchronizer |
| 20 18. | drive gearwheel | 45 45. | idler gearwheel |
| 19. | drive gearwheel | 46. | output shaft |
| 20. | drive gearwheel | 47. | gearwheel |
| 21. | 1st layshaft | 48. | gearwheel |
| 22. | idler gearwheel | 49. | idler gearwheel |
| 25 23. | idler gearwheel | 50 50. | synchronizer |
| 24. | idler gearwheel | | |

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C l a i m s

1. A method for controlling a double-clutch
transmission (2), the transmission (2) having two
5 transmission sub-units (15, 17, 18, 22, 23, 29, 30;
16, 19, 20, 24, 31, 32) capable of assuming a
plurality of shifting states, wherein one of the
sub-units (15, 17, 18, 22, 23, 29, 30; 16, 19, 20,
24, 31, 32) has shifting states associated to a
10 first set of gears and the other sub-unit has
shifting states associated to a second set of gears,
and both sub-units are capable of assuming a
shifting state associated to a given gear of their
associated set at the same time, the method
15 comprising the steps of
 - a) detecting whether the transmission is in a
steady state of operation (S1, S3, S5, S7, S8) in
which a first one of said sub-units is in a shifting
state associated to a gear and is bearing a load,
20 whereas the second sub-unit is idle;
 - b) if a steady state is detected, determining
among the shifting states of the idle sub-unit,
depending on at least the associated gear of the
load-bearing sub-unit, the shifting state in which
25 losses are smallest (S9);
 - c) placing the idle sub-unit in the determined
shifting state (S10).
2. The method of claim 1, wherein the first set of
30 gears comprises odd gears and the second set of
gears comprises even gears.
3. The method of claim 1 or 2, wherein the shifting
states of each sub-unit comprise a neutral state.

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4. The method of claim any of the preceding claims, wherein the shifting state of the idle sub-unit is determined depending further on the speed of a drive shaft (3).
- 5
5. The method of any of the preceding claims, wherein a steady state of operation is detected if one or more of the following criteria is fulfilled:
- 10 a) a driver-operated mode selector is set so as to allow detection of the steady state (S1);
- b) the clutch associated to the load-bearing input shaft is closed;
- c) the rate of change of the speed of the drive shaft (3) is below a predetermined threshold (S8);
- 15 d) the rate of change of the position of an accelerator pedal is below a predetermined threshold (S7).
6. The method of any of the preceding claims, wherein at least one shifting threshold speed ($swt_{sup}(n)$, $swt_{inf}(n)$) of the drive shaft (3) is associated to each of its gears, and a steady state of operation is detected if the difference between the speed of the drive shaft (3) and each gear switching
- 25 threshold speed ($swt_{sup}(n)$, $swt_{inf}(n)$) of a currently active gear (n) is above a predetermined threshold.
7. The method of any of the preceding claims, wherein the shifting state in which losses are smallest is determined (S9) by consulting a look-up table (10).
- 30
8. A controller (5) for a vehicle transmission adapted to carry out the method of any of the preceding claims.

9. The controller of claim 8, wherein a mode selector (9) is provided for choosing between at least first economic and sport driving modes, which use different algorithms for selecting the active gear of the transmission (2) depending on driving conditions, and execution of the method is enabled in the first economic mode and is disabled in the sport mode.
10. The controller of claim 9, wherein the mode selector (9) further supports selection of a second economic mode which uses the same algorithm for selecting the active gear as the first economic mode, and execution of the method is disabled in the second economic mode.
11. The controller of claim 9 or 10, wherein the first economic mode is automatically pre-selected upon start-up.
12. A computer program product comprising program code means for enabling a computer, when carried out on it, to execute the method of one of claims 1 to 7.
13. A recording medium (10) having recorded on it, in computer executable form, the computer program product of claim 12.

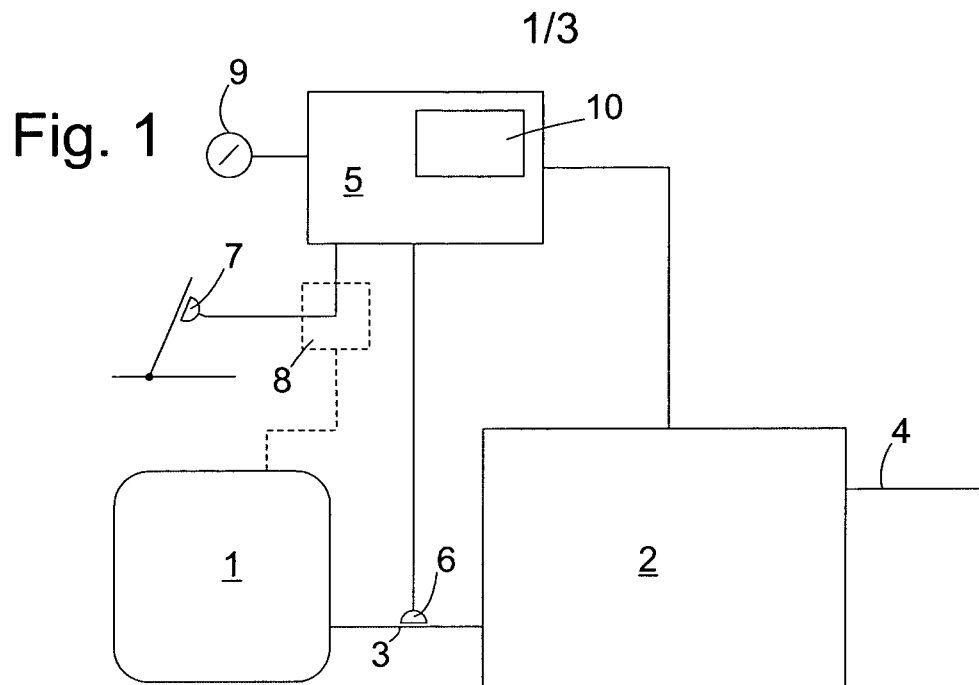
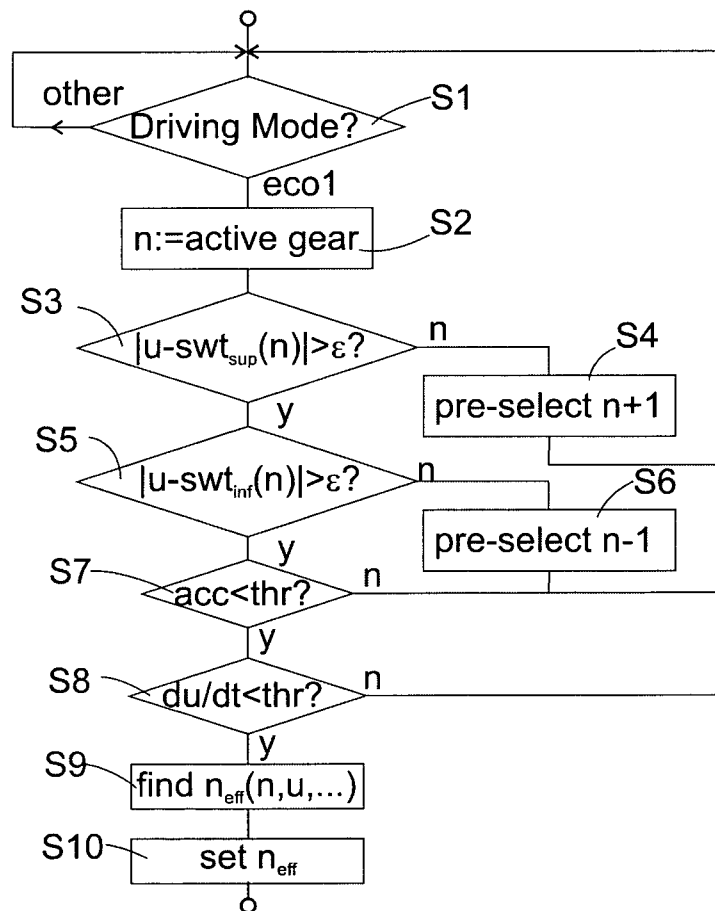
**Fig. 2**

Fig. 3

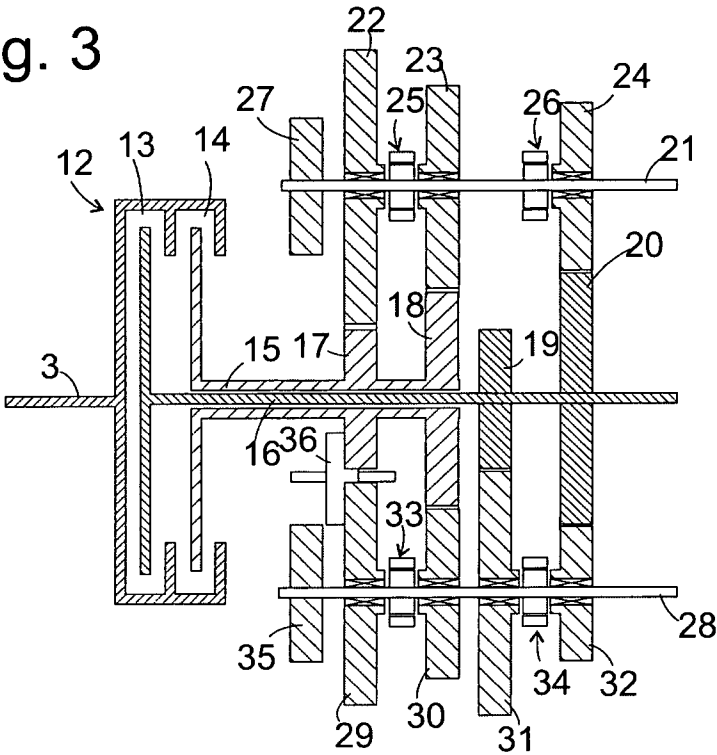


Fig. 4

pre- sel.	idle	1	2	3	4	5	6
active							
1	+		+	-	+	-	+
2	+	+		+	-	+	-
3	+	-	+		+	-	+
4	+	+	-	+		+	-
5	+	-	+	-	+		+
6	+	+	-	+	-	+	

Fig. 5

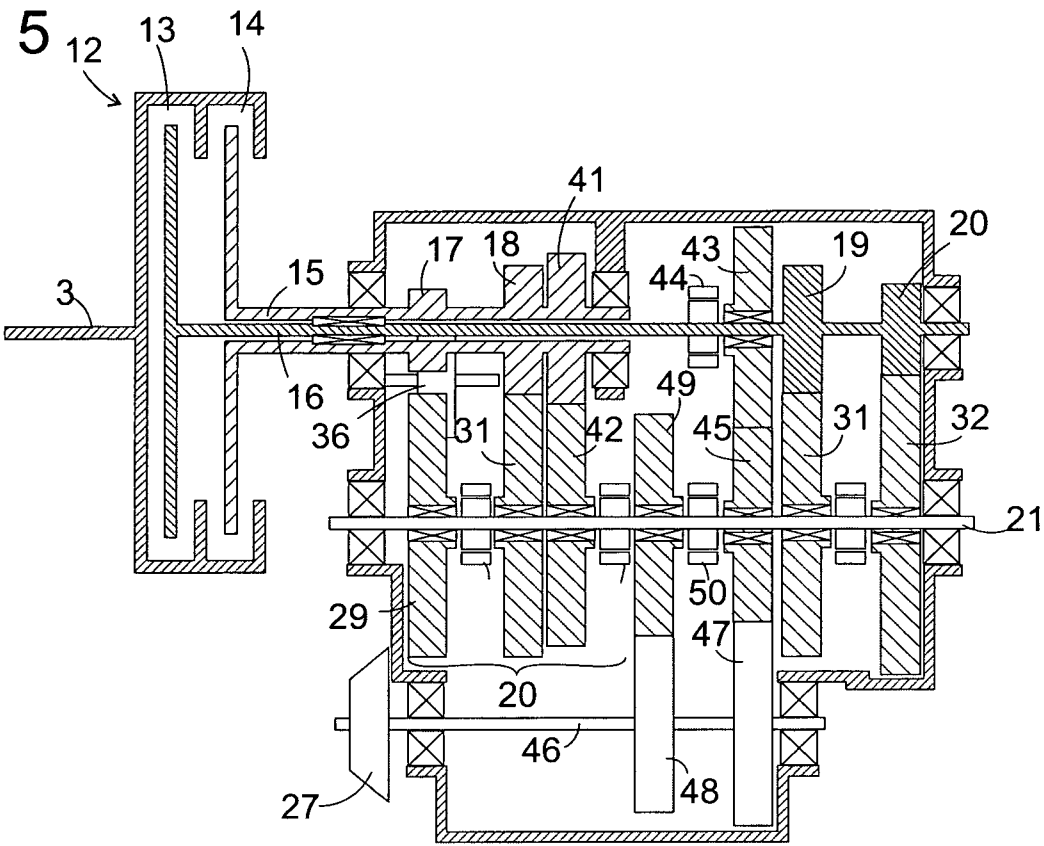


Fig. 6

pre- sel. active	idle	1	2	3	4	5	6	7	8
	1	2	3	4	5	6	7	8	
1	+	+	-	+	-	-	-	-	-
2	+	+	+	-	+	-	-	-	-
3	+	-	+	+	-	-	-	-	-
4	+	+	-	+	+	-	-	-	-
5	+	-	+	-	+	-	-	-	-
6	+	-	-	-	-	-	+	-	-
7	+	-	-	-	-	+	-	+	-
8	+	-	-	-	-	-	-	+	+

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2009/008343

A. CLASSIFICATION OF SUBJECT MATTER
INV. F16H61/688

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 practical, 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 1 072 820 A2 (VOLKSWAGEN AG [DE]) 31 January 2001 (2001-01-31) paragraphs [0002], [0007], [0009]	1-5, 7-8, 12-13
A	EP 1 450 074 A2 (BORG WARNER INC [US]) 25 August 2004 (2004-08-25) abstract; figure 1	1-13
A	EP 1 803 978 A1 (HONDA MOTOR CO LTD [JP]) 4 July 2007 (2007-07-04) abstract; figure 1	1-13
A	DE 102 53 616 A1 (VOLKSWAGEN AG [DE]) 27 May 2004 (2004-05-27) abstract; figure 1	1-13



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Date of the actual completion of the international search

16 February 2010

Date of mailing of the international search report

25/02/2010

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Information on patent family members

International application No

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