

(51) International Patent Classification:
F16H 3/093 (2006.01)(21) International Application Number:
PCT/GB2009/002528(22) International Filing Date:
22 October 2009 (22.10.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0819365.8 22 October 2008 (22.10.2008) GB
0905946.0 6 April 2009 (06.04.2009) GB
0906230.8 9 April 2009 (09.04.2009) GB(71) Applicant (for all designated States except US): **ZE-ROSHIFT LIMITED** [GB/GB]; Davy Avenue, Knowlhill, Milton Keynes MK5 8PB (GB).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **MARTIN, William, Wesley** [NZ/GB]; 8 Skeats Wharf, Pennyland, Milton Keynes MK15 8AY (GB). **QUINN, Richard, Neil** [GB/GB]; 63 Deacon Place, Middleton, Milton Keynes MK10 9FS (GB).(74) Agent: **MORRIS, Jonathan, Paul**; Urquhart-Dykes & Lord LLP, Midsummer House, 413 Midsummer Boulevard, Central Milton Keynes MK9 3BN (GB).

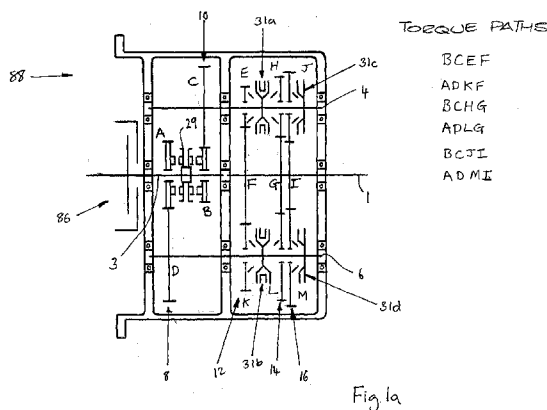
(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, 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).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: POWERSHIFT TRANSMISSION



(57) **Abstract:** A transmission system, for example for a vehicle. The transmission system includes first, second, third and fourth shafts (3, 4, 6, 1), wherein the second and third shafts (4, 6) are lay shafts; a first gear train (8) for transmitting drive between the first and second shafts (3, 1) including a first gear element (B) rotatably mounted on the first shaft (3) and a second gear element (C) mounted on the second shaft (4); a second gear train (10) for transmitting drive between the first and third shafts (3, 6) including a third gear element (A) rotatably mounted on the first shaft (3) and a fourth gear element (D) mounted on the third shaft (8); and a third gear train (12) for transmitting drive between the second and fourth shafts (4, 1) and/or the third and fourth shafts (6, 1). The transmission system also includes a first selector assembly (29) arranged to selectively lock each of the first and third gear elements (B, A) for rotation with the first shaft (3) from operational modes that include the following modes: lock the gear element (B, A) for rotation with the first shaft (3) in the clockwise and anti-clockwise directions; lock the gear element (B, A) for rotation with the first shaft (3) in the clockwise direction and not lock in the anti-clockwise direction; and lock the gear element (B, A) for rotation with the first shaft (3) in the anti-clockwise direction and not lock in the clockwise direction; and damping means (200) for damping engagement of the first and third gear wheels (B, A) by the first selector assembly (29).

POWERSHIFT TRANSMISSION

The present invention relates to a transmission system.

This application refers to a system and method for the elimination of a failure mode that can occur in instantaneous type transmission systems, for example of the type described in WO 2004/099654, WO 2005/005868, WO 2005/005869, WO 2005/024261 and WO 2005/026570. However, similar problems may occur in other types of transmission systems.

The known systems disclosed in the above-mentioned publications are examples of instantaneous transmission systems. The known transmissions have a plurality of gear trains for transmitting drive between a transmission input shaft and a transmission output shaft. For a first gear train, a first gear wheel is rotatably mounted on one of a transmission input shaft and an output shaft and a second gear wheel is fixed to the other shaft, in mesh with the first gear wheel. A second gear train comprising third and fourth gear wheels is similarly arranged. The transmission also includes at least one gear selector mechanism that is located between the rotatably mounted gear wheels that is arranged to selectively lock them for rotation with the shaft on which they are mounted. When a gear wheel from a gear train is locked for rotation with the shaft, drive is transmitted between the input and output shafts via that gear train.

The arrangement is such that when drive is transmitted between the input and output shafts via one of the gear trains, for example the first gear train, the gear selector mechanism can select the new (second) gear train under power without disengaging the first gear train, by locking the rotatably mounted gear wheel of the second gear train to its shaft. Thus momentarily, drive is transmitted between the input and output shaft via two gear trains. The new gear train then overdrives the first gear train and the selector mechanism disengages the first gear wheel. Drive is then transmitted between the input and output shafts via the new gear train only, thus providing uninterrupted power through a gearshift. The selector mechanism is arranged such that the gearshifts can take place under acceleration or deceleration.

The gear selector mechanisms of the known transmissions have four modes with respect to each adjacent gear train:

Fully engaged in both torque directions (fully in gear);

Disengaged in both torque directions (neutral);

Engaged in the forward torque direction while disengaged in the reverse torque direction;

Disengaged in the forward torque direction while engaged in the reverse torque direction.

The last two of the above four modes enable a discrete ratio gearbox to have the ability to shift up or down ratios instantly under load without torque interruption.

There is an inherent failure mode in any gearbox with more than two gear trains that has both of the last two modes. Thus it is possible in instantaneous transmission systems having at least three gear trains for two gears to be engaged simultaneously with opposing modes under some conditions, which causes the transmission to lock up. One of the most dangerous scenarios is if the direction of torque changes during a shift. If torque has a constant known direction during a shift, the natural sequence of events prevents the above failure mode. During a sudden reversal of the direction of torque immediately prior to, or during a shift, there is potential for the above failure mode to occur.

A transmission system typically includes at least three gear trains, and is likely to include four to six gear trains. A transmission having four gear trains requires two instantaneous gear selector mechanisms. The first gear selector mechanism is arranged to selectively engage the first and second gear trains and the second gear selector mechanism is arranged to selectively engage the third and fourth gear trains. Each gear selector mechanism includes first and second sets of engagement members having opposing ends with fixed opposing directions of torque transfer. This provides an inherent fail-safe arrangement against the above mentioned failure mode where the shift is from a gear on one side of the hub (selector mechanism) to a gear on the other side of the same hub, for example when the first selector mechanism selects between the first and second gears or when the second selector mechanism selects between the third and fourth gears.

The above failure mode can only occur if a gearshift is from a gear that is engageable by one of the gear selector mechanisms to a gear that is engageable by the other gear selector mechanism, for example when changing between second and third gears in the four speed transmission mentioned above, since this requires movement of both the first and second gear

selector mechanisms. The first gear selector mechanism has to move out of engagement with the second gear train and the second gear selector mechanism has to move into engagement with the third gear train. If a torque reversal occurs when the second gear is still engaged by the first selector mechanism and the third gear is engaged by the second selector mechanism,
5 the transmission may lock up.

The transmission described in WO2006/095140 addresses the above-mentioned problems by using a layout that is inherently safe. The layout ensures that each gear change takes place across the hub of a single gear selector devices, which is inherently safe. This is achieved by including a gear train that is arranged to be selected by the first and second instantaneous gear
10 selector devices and by alternating subsequent gear selector devices on the input and output shafts of the transmission. WO 2006/123166 teaches another layout for addressing this problem.

WO 2005/0058648 describes an electronic control system for measuring the direction of torque in the gearbox and managing some shifts such as a kick-down shift. By measuring the
15 magnitude and direction of torque on all shifts it is possible to prevent gearbox lock up due to conflicting modes being engaged in two gears at once. However, control systems are complex and may introduce new failure modes into the transmission system. Since the control system does not affect the relative positions of the gear trains and the selector mechanisms in the instantaneous transmissions described above, the transmission layout remains inherently
20 prone to the failure-modes mentioned above should a problem occur with the control system.

In transmission systems where the selection of a new gear ratio takes place almost instantaneously without substantial power interruption large torque spikes can be generated when the new gear is engaged under certain shift conditions because the load impacting the gear wheel can be as high as 60kN.

25 The torque spikes cause shock waves to propagate through the transmission that can be heard and felt by the occupants of the vehicle. The shockwaves can produce a jerky ride for the car occupants and can lead to wear of transmission components and the possibility of components failing. Nevertheless it is highly desirable to use this type of transmission in vehicles since for many shift types there is no loss of drive during a gear change. This makes the vehicle more
30 efficient thereby requiring less fuel and producing lower emissions while at the same time

increasing the performance of the vehicle since the vehicle does not noticeably decelerate during an instantaneous shift.

WO 2005/005868 has addressed the torque spike problem by using a control system that reduces the vehicle clutch pressure prior to making a shift to at least partially absorb the large torque spikes generated when a new gear is engaged by relative rotational movement of the input and output sides of the clutch. However even with this system in place, known instantaneous transmission systems are noisy due to the inertia of the selector assembly colliding with the gear wheel at engagement. Thus such systems can fall below acceptable limits of Noise, Vibration and Harshness tests.

WO 2008/062192 discloses the use of gear elements each having a damping system built-into its structure to absorb the load when a new gear is selected. This effectively solves the torque spike problem since it reduces the magnitude of the spikes to a level that is not noticeable by the occupants of a vehicle. However, the designs disclosed in WO 2008/062192 are limited in their robustness and life expectancy. In some instances, the repeated loading that occurs when selecting a new gear causes the gear elements to fail in a period of time that is too short to be acceptable for use in road vehicles. In practice, it would be necessary for the transmission system to be repaired or replaced too frequently, which would be costly for the owner of the vehicle. Thus there is a need for instantaneous type transmission systems having means that mitigates the torque spike problem while at the same time having an arrangement that is sufficiently robust to meet the required life expectancy for road vehicles.

Accordingly the present invention seeks to provide an improved transmission system that mitigates at least some of the aforementioned problems or at least provides an alternative to known transmission systems.

According to one aspect of the invention there is provided a transmission system including first, second, third and fourth shafts, wherein the second and third shafts are lay shafts; a first gear train for transmitting drive between the first and second shafts including a first gear element rotatably mounted on the first shaft and a second gear element mounted on the second shaft; a second gear train for transmitting drive between the first and third shafts including a third gear element rotatably mounted on the first shaft and a fourth gear element mounted on the third shaft; a third gear train for transmitting drive between the second and fourth shafts and/or the third and fourth shafts; a first selector assembly arranged to

selectively lock each of the first and third gear elements for rotation with the first shaft from operational modes that include the following modes: lock the gear element for rotation with the first shaft in the clockwise and anti-clockwise directions; lock the gear element for rotation with the first shaft in the clockwise direction and not lock in the anti-clockwise direction; and lock the gear element for rotation with the first shaft in the anti-clockwise direction and not lock in the clockwise direction; and damping means for damping engagement of the first and third gear wheels by the first selector assembly.

The invention enables instantaneous shifts to be performed for the majority, if not all, of the gear ratios in the transmission, for at least some shift types, by actuation of a single instantaneous gear selector assembly and creating torque paths with the other selector assembly by preselecting gears. The arrangement also provides a common output which provides a well balanced and compact transmission. The layout avoids the lockup problem described in the introductory paragraphs since all instantaneous shifts are achieved by moving a single instantaneous selector assembly, which is inherently safe. The lockup problem only occurs when it is necessary to operate more than one instantaneous selector mechanism during a shift. And provides a system that can be easily scaled to provide the appropriate number of gear ratios by adding in additional gear trains and selector assemblies to create additional torque paths. A further advantage is that the layout is suitable for manufacture by existing dual clutch manufacturing facilities.

The invention also provides an alternative to dual clutch transmission systems. Dual clutch transmission systems have several draw backs: they are bulky, heavy, typically require wet clutches which are very expensive and require a pumping system to keep them continuously lubricated. Furthermore, although there is a very quick handover of torque during a shift by controlling the opening of one clutch and the closing of the other clutch, it is common for dual clutches to be operated at around 5% constant slip, which leads to losses in efficiency. The constant slip is required to address the 'stick-slip' phenomenon, which is that it requires a larger force to move two bodies from a fixed relationship with each than when they are already moving. Also, it is easier to control the operation of two bodies that are moving relative to each other than when they are initially static since there is greater variability in the force required to start two bodies rotating relative to each other from fixed positions than when they are already moving.

Advantageously the first and second lay shafts can be arranged substantially parallel to the input shaft and the distance between the longitudinal axis of the input shaft and the longitudinal axis of the first lay shaft is different from the distance between the longitudinal axis of the input shaft and the longitudinal axis of the second lay shaft.

- 5 Advantageously the output shaft is arranged substantially parallel to the input shaft and the longitudinal axis of the output shaft is offset from the longitudinal axis of the input shaft such that the input shaft and the output shaft are not co-axial.

Advantageously the gear trains are arranged in the form of a geometric spread.

- 10 Advantageously the first shaft can be an input shaft and the second shaft can be an output shaft. Alternatively, the first shaft can be an output shaft and the second shaft can be an input shaft.

Advantageously the selector assembly can select neutral by not locking either of the first and second gear elements for rotation with the shaft.

- 15 Advantageously the third gear train can be arranged to transmit drive between the second and fourth shafts and can include a fifth gear element rotatably mounted on the second shaft and a sixth gear element mounted on the fourth shaft, and the transmission system can include a second selector assembly arranged to selectively lock the fifth gear element for rotation with the second shaft. The third gear train can be further arranged to transmit drive between the third and fourth shafts and when so arranged, can include a seventh gear element rotatably
20 mounted on the third shaft, and the transmission system can include a third selector assembly arranged to selectively lock the seventh gear element for rotation with the third shaft. This provides a very compact way of transmitting drive between the second, third and fourth shafts.

- 25 The first gear train can be arranged to transfer drive between the first and third shafts and includes an eighth gear element rotatably mounted on the third shaft, the fourth gear element is rotatably mounted on the third shaft and the transmission system includes a fourth gear selector assembly for selectively locking the fourth and eighth gear elements for rotation with the third shaft. Advantageously the fourth selector assembly is a non-instantaneous selector assembly such as a synchromesh selector assembly. The fourth selector assembly can be
30 arranged to selectively engage the fourth and eighth gear elements from operational modes

that include the following operational modes: lock the fourth gear element for rotation with the third shaft and not lock the eighth gear element; lock the eighth gear element for rotation with the third shaft and not lock the fourth gear element; and lock both the fourth and the eighth gear elements for rotation with the third shaft. For example, the fourth selector assembly can be of the split synchromesh type.

The second gear train can be arranged to transfer drive between the first and second shafts and includes a ninth gear element rotatably mounted on the second shaft, the second gear element is rotatably mounted on the second shaft and the transmission system includes a fifth gear selector assembly for selectively locking the second and ninth gear elements for rotation with the second shaft. Advantageously the fifth selector assembly is a non-instantaneous selector assembly such as a standard or split synchromesh selector assembly. The fifth selector assembly can be arranged to selectively engage the second and ninth gear elements from operational modes that include the following operational modes: lock the second gear element for rotation with the third shaft and not lock the ninth gear element; lock the ninth gear element for rotation with the third shaft and not lock the second gear element; and lock both the second and the ninth gear elements for rotation with the third shaft. For example, the fifth selector assembly can be of the split synchromesh type.

Advantageously the transmission system can include a fourth gear train for transmitting drive between the third and fourth shafts, wherein said fourth gear train includes an eleventh gear element mounted on the fourth shaft and a twelfth gear element rotatably mounted on the third shaft, and wherein the third selector assembly is arranged to selectively lock the twelfth gear element for rotation with the third shaft. The fourth gear train can further include a tenth gear element rotatably mounted on the second shaft, and wherein the second selector assembly is arranged to selectively lock the tenth gear element for rotation with the second shaft. This provides a very compact arrangement for transmitting drive between the second, third and fourth shafts.

Advantageously the transmission system can include a fifth gear train including a thirteenth gear element rotatably mounted on the second shaft, a fourteenth gear element mounted on the fourth shaft and a fifteenth gear element rotatably mounted on the third shaft, and a sixth selector assembly arranged to selectively lock the thirteenth gear element for rotation with the second shaft and a seventh selector assembly arranged to selectively lock the fifteenth gear

element for rotation with the third shaft. Advantageously the fifth selector assembly is a non-instantaneous selector assembly such as a standard or split synchromesh selector assembly.

The second and third selector assemblies can be non-instantaneous selector assemblies such as of the synchromesh or dog type selector assemblies. The synchromesh assemblies can be of the split type or non-split type.

Advantageously at least some of the gear selector assemblies can select neutral, and preferably all of the selector assemblies can select neutral.

The first selector assembly includes first and second sets of engagement members that are arranged to selectively lock the first gear element for rotation with the first shaft. Advantageously the first selector assembly can be arranged to select one of the first and third gear elements while the other of the first and third gear elements is still engaged by the selector assembly.

Advantageously the selector assembly is arranged such that when a driving force is transmitted, one of the first and second sets of engagement members drivingly engages the engaged gear element, and the other set of engagement members is then in an unloaded condition. The selector assembly can be arranged such that when a braking force is transmitted the first set of engagement members drivingly engages the engaged gear element, and the second set of engagement members is in an unloaded condition, and when a driving force is transmitted the second set of engagement members drivingly engages the engaged gear element, and the second set of engagement members is then in an unloaded condition.

Each of the first and third gear elements includes first and second parts that are arranged to rotate relative to each other and a damping system for damping the relative rotational movement. Advantageously the first part can include a first set of drive formations, the second part can include a second set of drive formations, and when selecting the gear element with one of the first and second sets of engagement members, that set of engagement members is arranged to drivingly engage the second set of drive formations to cause relative rotational movement between the first and second parts of the gear element, the damping system is arranged to damp the relative rotational movement between the first and second parts of the gear element, and after some damping has occurred the engagement members are arranged to drivingly engage the first set of drive formations. Having first and second sets of drive formations on the gear element enables damping to take place when the gear element is

initially engaged and subsequently provides a rigid drive connection between the first part of the gear element and the selector assembly such that the damping system is not continuously loaded when the gear element is selected. This significantly increases the life expectancy of the gear element, and hence the transmission system, which makes the transmission system
5 suitable for road vehicles. This provides a significant improvement on the systems disclosed in WO 2008/062192.

The damping system is arranged to allow lost motion between the first shaft and at least one of the first gear element and the first selector assembly after the selector assembly engages the first gear element. The inventors have discovered that lost motion between the selector
10 assembly and the first gear element reduces noise to an acceptable level, that is, such that it cannot be heard in an automobile during normal use. This is because the lost motion increases the time that it takes the selector assembly to lock the first gear element for rotation with the first shaft after the initial engagement thereby softening the impact.

Advantageously the damping system is a fluid damping system, and preferably a hydraulic
15 damping system. The fluid damping system is arranged to damp relative rotational movement between the first and second parts in the clockwise and anti-clockwise directions.

Advantageously the damping system can include first and second piston chambers located in the second part of the gear element and a first piston that is arranged to move with the first part of the gear element and to move into and out of the first and second piston chambers
20 according to the relative rotational movement of the first and second parts of the gear element. The damping system can include third and fourth piston chambers located in the second part of the gear element and a second piston that is arranged to move with the first part of the gear element and to move into and out of the third and fourth piston chambers according to the relative rotational movement of the first and second parts of the gear element.

25 The first and second pistons and each of their respective piston chambers are arranged to allow hydraulic fluid to leak from the chambers during a damping action.

One of the first and second parts of the gear element includes meshing means for meshing with another gear element, and the other of the first and second parts of the gear element includes means for mounting the gear element on a shaft. The first and second parts of the
30 gear element are fitted together, the first and second sets of drive formations are located on the same side face.

The first set of drive formations can include n drive formations, wherein n is in the range 2 to 24, preferably 3 to 16 and more preferably 3 to 6, and the second set of drive formations can include n drive formations, wherein n is in the range 2 to 10, preferably 3 to 6. The drive formations in the first set of drive formations are distributed on the first part of the gear element such that they are substantially equally angularly spaced. The drive formations in the second set of drive formations are distributed on the second part of the gear element such that they are substantially equally angularly spaced.

Advantageously the transmission system can include means for limiting the axial movement of the first and second sets of engagement members. The means for limiting the axial movement of the first and second sets of engagement members includes at least one of: a set of raised abutments, wherein the raised abutments are located on the second part of the gear element and are arranged alternately with the drive formations in the second set of drive formations; and the first set of drive formations, the depth dimension being selected to determine the extent of axial limitation of the first and second sets of engagement members.

Advantageously the damping system can include means for self-centring the relative rotational orientations of the first and second parts of the gear element such as resilient means, for example a spring element.

Advantageously when in an unloaded condition, the drive formations of the first set of drive formations are rotationally offset from the drive formations in the second set of drive formations, and when in an unloaded condition, the drive formations of the first set of drive formations are rotationally aligned with the drive formations in the second set of drive formations.

Advantageously the damping fluid is supplied to the interior of the gear element via the first shaft. For example, the fluid can be supplied by an integral or an external pump. An integral pump is preferred for newly designed transmission systems. An external pump is preferred when an existing transmission system is modified to include the fluid damping system.

Advantageously the first gear selector assembly is arranged to select the following operational mode with respect to the first gear element: the first gear element is not locked for rotation with the first shaft in the clockwise or anticlockwise directions.

The transmission system can include an electronically programmable control system for controlling operation of the or each gear selector assembly. For example, the control system may include a processing device that is programmed to control operation of the selector assemblies. This can prevent transmission lock up occurring by appropriate sequence control.

5 Advantageously the control system can be arranged to move the unloaded set of engagement members out of engagement from the engaged gear element before actuating the other gear selector assembly to engage the new gear wheel. This is an important factor in preventing transmission lock up when torque reversals occur during a shift requiring the operation of more than one selector assembly since it removes the set of engagement elements out of
10 engagement with the current gear wheel that would otherwise lock the transmission if a torque reversal occurred.

The control system can be arranged to control the operation of the or each selector mechanism to perform sequential gear shifts. The control system can be arranged to bias the loaded set of engagement members towards the unengaged gear wheel until the loaded set of engagement
15 members are free to move.

Advantageously the transmission system can include means for determining the direction of torque in the transmission system when receiving a request for a gearshift. Preferably the transmission includes a sensor device, such as a speed sensor for detecting the rotational speed of at least one transmission component or transmission input, and the control system
20 determines from the sensor device the rate of change of rotational speed. This enables the sensor device to determine the direction of torque in the transmission, that is, whether there is an accelerating or braking force being applied. Instead of using a sensor device, the direction of torque can be determined by calculation from other known quantities, including the engine speed.

25 The control system can be arranged to prevent the direction of torque in the transmission changing during a gearshift.

According to another aspect of the invention there is provided a transmission system including first, second, third and fourth shafts, wherein the second and third shafts are lay shafts; a first gear train for transmitting drive between the first and second shafts including a
30 first gear element rotatably mounted on the first shaft and a second gear element mounted on the second shaft; a second gear train for transmitting drive between the first and third shafts

including a third gear element rotatably mounted on the first shaft and a fourth gear element mounted on the third shaft; a third gear train including a fifth gear element rotatably mounted on the second shaft, a sixth gear element mounted on the fourth shaft and a seventh gear element rotatably mounted on the third shaft; a first gear selector assembly for selectively
5 transmitting torque between the first shaft and the first gear element and between the first shaft and the third gear element, said first selector assembly including first and second sets of engagement members that are moveable into and out of engagement with the first and third gear elements and an actuator system for actuating the engagement members, wherein the first gear selector assembly is arranged such that when a driving force is transmitted, one of the
10 first and second sets of engagement members drivingly engages the engaged gear element, and the other set of engagement members is then in an unloaded condition and the actuator system is arranged to move the unloaded set of engagement members into driving engagement with the unengaged gear element to effect a gear change, damping means for damping engagement of the first and third gear wheels by the first selector assembly, a second
15 selector assembly arranged to selectively lock the fifth gear element for rotation with the second shaft; and a third selector assembly arranged to selectively lock the seventh gear element for rotation with the third shaft.

Advantageously the first selector assembly can be arranged such that when a braking force is transmitted the first set of engagement members drivingly engages the engaged gear wheel,
20 and the second set of engagement members is in an unloaded condition, and when a driving force is transmitted the second set of engagement members drivingly engages the engaged gear wheel, and the first set of engagement members is then in an unloaded condition.

The actuator system for the first selector assembly can include a first actuator device for actuating the first set of engagement members and a second actuator device for actuating the
25 second set of engagement members independently of the first actuator device. Preferably the actuator system includes a first actuator member for moving the first set of engagement members and a second actuator member for moving the second set of engagement members, which can be actuated by the first and second actuator devices respectively. The actuator assembly can include at least one resilient means arranged to move at least one of the first and
30 second sets of engagement members into engagement with the first and second gear elements when the engagement members are in unloaded conditions. Preferably the or each resilient means is arranged to bias at least one of the first and second sets of engagement members

towards the first or second gear element when the engagement members are drivingly engaged with a gear element.

Advantageously the second aspect of the invention can include first and third gear elements that include damping systems as described above.

- 5 The first selector assembly is arranged such that when the first and second sets of engagement members engage one of the first and second gear elements the backlash when moving between acceleration and deceleration is less than or equal to five degrees.

The first and second sets of engagement members preferably comprise between two and eight members, more preferably between two and four members, and more preferably still three
10 members. Advantageously the first shaft may include keyways arranged such that the first and second sets of engagement members can slide axially along the keyways and to radially restrain the positions of the sets of engagement members. Preferably the cross-section of the keyways is one of T-shaped, slotted, and dovetailed.

Embodiments of the invention will now be described by way of example only with reference
15 to the accompanying drawings, in which:

Figure 1a is a schematic representation of a transmission system layout according to the invention;

Figure 1b is a schematic representation of a selector mechanism used in the transmission system of Figure 1a;

20 Figure 1c is a schematic of a vehicle drive system including a transmission system in accordance with the invention;

Figures 2a to 2j show a gear wheel having a damping mechanism;

Figure 3 is a schematic that illustrates the interaction of a selector mechanism and the dogs on the side of a gear wheel;

25 Figure 4 is an isometric view of an engagement element from the selector mechanism;

Figures 5a-f illustrate diagrammatically operation of the selector mechanism by showing movement of one engagement member from each set;

Figures 6a and 6b show a second embodiment of the invention, having an alternative transmission layout from Figure 1a; and

Figures 7a and 7b show a variant of the second embodiment of the invention.

Figure 1a shows a transmission system 88 that includes an input shaft 3, an output shaft 1 a first lay shaft 4 and a second lay shaft 6. Drive is transferred from the input shaft 3 to the output shaft 1 via the first or second lay shafts 4,6 using gear trains and selector assemblies to create the torque path for each gear ratio.

The gear trains are arranged as follows: a first gear train 8 including a gear A mounted on the input shaft 3 via a bearing so that it can rotate relative to the input shaft 3 and a gear D mounted on the second lay shaft 6 so that it rotates with the second lay shaft 6; a second gear train 10 including a gear B mounted on the input shaft 3 via a bearing so that it can rotate relative to the input shaft 3 and a gear C mounted on the first lay shaft 4 so that it rotates with the first lay shaft 4; a third gear train 12 including a gear E mounted on the first lay shaft 4 via a bearing so that it can rotate relative to the first lay shaft 4, a gear F mounted on the output shaft 1 so that it rotates with the output shaft 1 and a gear K mounted on the second lay shaft 6 via a bearing so that it can rotate relative to the second lay shaft 6; a fourth gear train 14 including a gear H mounted on the first lay shaft 4 via a bearing so that it can rotate relative to the first lay shaft 4, a gear G mounted on the output shaft 1 so that it rotates with the output shaft 1 and a gear L mounted on the second lay shaft 6 via a bearing so that it can rotate relative to the second lay shaft 6; and a fifth gear train 16 including a gear J mounted on the first lay shaft 4 via a bearing so that it can rotate relative to the first lay shaft 4, a gear I mounted on the output shaft 1 so that it rotates with the output shaft 1 and a gear M mounted on the second lay shaft 6 via a bearing so that it can rotate relative to the second lay shaft 6.

An instantaneous gear selector mechanism 29 is mounted on the input shaft 3 between the gears A and B and is arranged to selectively lock the gears A and B for rotation with the input shaft 3 in a manner described below. A first synchromesh selector mechanism 31a is mounted on the first lay shaft 4 between the gears E and H and is arranged to selectively lock the gears E and H for rotation with the first lay shaft 4; a second synchromesh selector mechanism 31b is mounted on the second lay shaft 6 between the gears K and L and is arranged to selectively lock the gears K and L for rotation with the second lay shaft 6; a third synchromesh selector mechanism 31c is mounted on the first lay shaft 4 adjacent gear J and is arranged to

selectively lock gear J for rotation with the first lay shaft 4; and a fourth synchromesh selector mechanism 31d is mounted on the second lay shaft 6 adjacent gear M and is arranged to selectively lock gear M for rotation with the second lay shaft 6. The synchromesh selector mechanisms 31a-d are of a conventional type.

- 5 The structure of the instantaneous selector mechanism 29 and the gear A, and the way the selector mechanism 29 selectively engages the gears A and B will now be described. The structure of the gear B is similar to the gear A. Each of the gears C to M is of the conventional type.

10 Figures 2a-j shows the gear A including a hydraulic damping mechanism 200 that is arranged to allow limited relative rotational movement between the gear A and the input shaft 3 and / or the selector mechanism 29. The arrangement is such that the limited relative rotational movement softens the engagement of the new gear A by the selector mechanism 29 thereby reducing the noise generated to acceptable levels. The relative rotational movement effectively increases the time that it takes for the gear A to be locked for rotation with the
15 input shaft 3 and thereby provides a longer period of time over which the energy generated by the collision is dissipated.

The gear A comprises an outer annular part 202 and an inner annular part 204. The inner part 204 is arranged co-axially with the outer part 202 and is arranged for limited relative rotational movement therewith. The outer part 202 includes gear teeth 210 formed in a
20 peripheral portion that are arranged to mate with teeth on a corresponding gear wheel fixed to the input shaft 3, and a set of drive formations in the form of a first set of dogs 212. The first set of dogs 212 includes six dogs 214 that are arranged to be engaged by the selector mechanism 29. The dogs 214 are preferably formed integrally with the outer part 202 of the gear wheel, but this is not essential, and are evenly circumferentially distributed about the side
25 face, i.e. the angle subtended between the centres of a pair of dogs 214 is approximately 60° (see Figure 2a). Each dog 214 is arcuate, extends through an angle of approximately 30°, and includes two drive faces 216, one at each end, and a substantially planar upper surface 218.

The inner part 204 is rotatably mounted on the input shaft 3 via a bearing 203 and includes a second set of dogs 220 on a side face that are arranged to be engaged by the selector
30 mechanism 29. The second set of dogs 220 is located on one side of the inner part of the gear wheel. The first set of dogs 220 comprises three dogs 222 evenly circumferentially distributed

about the gear face, i.e. the angle subtended between the centres of a pair of dogs is approximately 120° (see Figures 2a and 3), and are preferably formed integrally with the first gear wheel, but this is not essential. Each dog 222 extends through angle of approximately 30° , and includes two drive faces 224, one at each end, and a substantially planar upper surface 226. Three dogs are used because this arrangement provides large engagement windows, that is, spaces between the dogs, to receive the engagement elements. Large engagement windows provide greater opportunities for the first gear selector mechanism 29 to fully engage the gear A before transmitting drive thereto.

A set of raised abutments 228 is located on the same side face of the inner part of the gear wheel 204 as the second set of dogs 220 to prevent the selector mechanism 29 from engaging the first set of dogs 212 before the second set of dogs 220 is engaged. The set of raised abutments 228, includes three raised abutments 230 that are arranged alternately with the dogs 222. Each raised abutment 230 includes inclined end faces 232 and a substantially planar upper surface 234. Each raised abutment 230 extends through an arc of approximately 60° , is spaced by 15° from each adjacent dog 222, and has a depth that is substantially equal to the depth of the dogs 214 in the first set of dogs 212.

The inner gear part 204 includes two arcuate tracks 236 that are arranged about the longitudinal axis of the inner gear part in the manner shown in Figure 2j. Each track includes two piston chambers 238: one located towards each end of the track 238. Each track 236 is arranged to house a piston 240. Each piston 240 is arcuate and includes a connector 242 that protrudes through a slot 244 in the curved surface 246 of the inner gear part that sits in a recess formed in the outer gear part 202, the arrangement being such that each piston 240 rotates with the outer gear part 202. Thus each piston 240 is arranged to move along its track 236 into and out of each of the piston chambers 238 according to the relative rotational orientations of the inner and outer parts 204, 202 of the gear.

Preferably the inner gear 204 part is manufactured from first and second inner gear parts 205, 207 that are welded together, for example by electron beam welding.

The piston chambers 238 are filled with a hydraulic fluid, which is fed through the input shaft 3 along an axial feed line 248 formed in the input shaft 3 along its central axis, and to the chambers 238 via radial feed lines 250 and a feed ring 252. The feed ring 252 includes an annular groove formed in its outer surface to enable it to continuously supply oil to the

interior of the gear wheel. The oil supply system can be a closed system or an open system. For example, an open system can use the gearbox lubricating oil and include a system for pumping it from the sump of the gearbox to the interior of each gear wheel including the damping mechanism.

- 5 The movement of the pistons 240 along the tracks 236 is limited by hydraulic fluid being compressed within the piston chambers 238 and ultimately by the selector mechanism 29 drivingly engaging the first set of dogs 212 (see below).

The arrangement of the piston chambers 238, the pistons 240, and hydraulic fluid is such that there is a predetermined leakage rate under a given load as each piston 240 moves into one of
10 the piston chambers 238. This is achieved by dimensioning the piston 240 such that there are gaps between it and the inside of the piston chamber 238 to enable a small amount of hydraulic fluid to escape. The leakage rate provides a means of designing into the gear A the stiffness of the damping mechanism when the gear A is selected by the gear selector mechanism 29. For example, a typical leakage rate is typically less than 10% and preferably
15 around 5%.

The gear A includes a circlip 254, which acts as a self centring spring. The circlip 254 sits in a groove 256 formed in the curved surface 246 of the inner part of the gear. A lug 258 attached to the outer part of the gear 202 loads the circlip 254 when there is relative rotation between the inner and outer parts 204,202 of the gear. Thus when the load causing relative rotation
20 between the inner and outer parts 204,202 reduces, the circlip 254 biases the inner and outer parts 204,202 to the neutral position. A further advantage of using a circlip 254 is that it can be arranged such that it is rotationally balanced.

When the selector mechanism 29 engages the gear A, abutments 228 and first set of dogs 212 initially prevent full engagement from taking place. Thus the selector mechanism 29 is only
25 able to drivingly engage the second set of dogs 220. When engagement takes place, the selector mechanism 29 drives the second set of dogs 220, which causes relative rotational movement between the inner and outer parts 204,202 of the gear wheel. The relative rotational movement causes each of the pistons 240 to move into one of its respective piston chambers 238 according to the direction of movement thereby loading the hydraulic fluid
30 located therein and causing a quantity to be forced out of the chamber 238. The effect of this is to damp the engagement of the gear A.

The first set of dogs 212 also acts as drive formations. When a predetermined amount of relative rotational movement occurs between the inner and outer parts 204,202 of the gear wheel, the selector mechanism 29 drivingly engages the first set of dogs 212. This prevents further relative rotational movement since the selector mechanism 29 then drives the outer part 202 of the gear wheel directly.

A similar effect occurs if the selector mechanism 29 engages the gear A in the opposite torque direction. Thus damping takes place in both the clockwise and anti-clockwise directions.

Thus the damping system reduces the noise of the impact such that it is not audible by the driver of the vehicle or so that it is reduced to an agreeable level.

The first gear selector mechanism 29 includes a sleeve 34, first and second sets of engagement elements 35,36 and an actuator assembly 38.

The first gear selector mechanism 29 is mounted on the input shaft 3 between the gears A and B. The gear selector mechanism 29 is arranged to engage the first and second sets of dogs 212,220 located on the gears A,B. The gears A,B are mounted spaced apart on the input shaft 3 and are arranged such that the sides including the first and second dog groups 212,220 face each other.

The first and second sets of engagement elements 35,36 are mounted on the sleeve 34. The first set of engagement elements 35 comprises three elements 28 that are evenly distributed about the input shaft 3 such that their bases face inwards, and the axes of the elements 28 are substantially parallel with each other and the input shaft 3. The second set of engagement elements 36 comprises three elements 30, which are similarly arranged about the input shaft 3. The sets of engagement elements 35,36 are arranged to rotate with the input shaft 3 but are able to slide axially along the sleeve 34, and hence the input shaft 3, in response to a switching action of the actuator assembly 38. To facilitate this, the sleeve 34 includes six keyways 41 formed in its curved surface with each engagement element 28,30 having a complementary formation in its base. The keyways 41 may have substantially T-shaped profiles such that the elements are radially and tangentially (but not axially) restrained within the keyways 41 (see Figure 3). Alternatively, the keyways 41 can have slotted or dovetailed profiles to radially restrain the elements.

Preferably the elements are configured to be close to the input shaft 3 to prevent significant

cantilever effects due to large radial distances of loaded areas thus reducing the potential for structural failure.

The arrangement of the engagement element sets 35,36 is such that elements of a particular set are located in alternate keyways 41 and the sets 35,36 can slide along the sleeve 34. The engagement elements in each set are rigidly connected to each other by an annular member 100 and move as a unit. Each set 35,36 can move independently of the other. The annular member 100 has a groove 102 formed in its outer curved surface that extends fully around the annular member. The engagement elements 28 in the first set of engagement elements 35 are preferably integrally formed with its annular member 100, though this is not critical. The engagement elements 28 are evenly distributed about the annular member 100. The second set of engagement elements 36 comprises three elements 30, which are held in a similar fixed arrangement by a second annular member 100. When there is relative movement between the first and second sets of engagement elements 35,36, the annular member 100 of the first engagement element set 35 moves over the second set of engagement elements 36 and the annular member 100 of the second engagement element set 36 slides over the first set of engagement elements 35.

Each engagement element 28 in the first engagement element set 35 has a first end 28a arranged to engage the first and second group of dogs 212,220 attached to the gear A and a second end 28b arranged to engage the first and second groups of dogs 212,220 on the gear B. The first and second ends 28a,28b typically have the same configuration but are opposite handed, for example the first end 28a is arranged to engage the first and second groups of dogs 212,220 during deceleration (reverse torque direction) of the gear A and the second end 28b is arranged to engage the first and second group of dogs 212,220 during acceleration (forward torque direction) of the gear B. Each engagement element 30 in the second engagement element set 36 is similarly arranged, except that the first end 30a is arranged to engage the first and second group of dogs 212,220 on gear A during acceleration of the and the second end 30b is arranged to engage the first and second group of dogs 212,220 during deceleration of the gear B.

When both the first and second sets of engagement elements 35,36 engage a gear wheel drive is transmitted between the input and output shafts 3,1 whether the gear is accelerating or decelerating.

The first and second ends 28a,30a,28b,30b of each engagement element include an engagement face 43 for engaging the first and second sets of dogs 212,220, a ramp 45, an end face 42 and may include a shoulder 44 (shown diagrammatically in Figure 4). The end faces 42 limit the axial movement of the engagement elements 28,30 by abutting the sides of the gear wheels and also the upper surfaces 218,234 of the first set of dogs and abutments respectively. The engagement faces 43 may be angled to complement the drive faces of the dogs 216,224 so that as the engagement elements 28,30 rotate into engagement, there is face-to-face contact to reduce wear. Each ramp 45 is preferably helically formed and slopes away from the end face 42. The angle of inclination of the ramp 45 is such that the longitudinal distance between the edge of the ramp furthest from the end face 42 and the plane of the end face 42 is larger than the height of the dogs 212,220. This ensures that the transmission does not lock up when there is relative rotational movement between the engagement elements 28,30 and the dogs 212,220 that causes the ramp 45 to move towards engagement with the dogs 212,220. The dogs 212,220 do not crash into the sides of the engagement elements 28,30 but rather engage the ramps 45. As further relative rotational movement between the dogs 212,220 and the engagement elements 28,30 occurs, the dogs 212,220 slide across the ramps 45 and the helical surfaces of the ramps cause the engagement elements 28,30 to move axially along the input shaft 3 away from the dogs 212,220 so that the transmission does not lock up. The ramps 45 are also arranged to interact with the inclined end faces 232 of the abutments in order to move axially away from the gear A.

The arrangement of the gear selector mechanism is such that it inherently prevents lockup of the transmission occurring when selecting a new gear.

Thus the selector assembly 29 is arranged to engage each of the gears A,B from the following modes: fully engaged in both torque directions (fully in gear); disengaged in both torque directions (neutral); engaged in the forward torque direction while disengaged in the reverse torque direction; and disengaged in the forward torque direction while engaged in the reverse torque direction. Since the first and second sets of engagement elements 35,36 can move independently of each other, it is possible to select a new gear A,B while the current gear A,B is still engaged and thus the selector mechanism 29 can perform instantaneous gear shifts since there is no loss of power when selecting a new gear, for at least some shift types.

When the engagement elements of the first and second sets 35,36 are interleaved, as in Figure 3, the engagement faces 43 of the first ends 28a of the first set of engagement elements 35 are

adjacent the engagement faces 43 of the first end 30a of the second set of engagement elements 36. When the first and second sets of engagement elements 35,36 are fully engaged with a gear, a dog 214 from the first set of dogs and a dog 222 from the second set of dogs is located between each pair of adjacent engagement faces 43. The dimensions of the dogs 214,222 and the ends of the elements are preferably such that there is little movement of each dog between the engagement face 43 of the acceleration element and the engagement face 43 of the deceleration element when the gear moves from acceleration to deceleration, or vice versa, to ensure that there is little or no backlash in the gear.

The actuator assembly 38 controls the movement of the first and second sets of engagement elements 35,36. The assembly 38 includes first and second actuators 46,64 and first and second actuator members 48,58. The first and second actuators 46,64 are force generator actuators and preferably part of an electrical system for example, an electro-mechanical system or an electro-hydraulic system. The first and second actuator members 48,58 are preferably in the form of independently controllable forks. Movement of the first set of engagement elements 35 is controlled by movement of the first actuator member 48, which is controlled by the first actuator 46. Movement of the second set of engagement elements 36 is controlled by movement of the second actuator member 58, which is controlled by the second actuator 64. Thus the first and second sets of engagement elements move totally independently of each other unlike known systems, such as the system of WO 2004/099654, which only has a single actuator for controlling actuation of both sets of engagement elements. With the known systems the sets of engagement elements can move relative to each other however the actuation of each set of engagement elements is interdependent since there is only a single actuator for initiating movement.

Each actuator member 48,58 is arranged to extend approximately 180 degrees around the groove 102 of its respective set of engagement elements and includes a semi-annular part that is located within the groove 102. Each set of engagement elements 35,36 can rotate relative to its respective actuator member 48,58 and is caused to move axially along the input shaft 3 by the actuator member 48,58 applying a force to the annular member 100.

Optionally the actuator assembly 38 may include resilient means, such as helical springs (not shown). The springs are arranged to bias the first and second sets of engagement elements to move in an axial direction when they are in driving engagement with a gear wheel and are unable to move. For example, the springs may be positioned between the first actuator 46 and

the first actuator member 48 or between the first actuator member 48 and the first set of engagement elements 35,36.

Operation of the first and second actuators 46,64, and hence movement of the first and second sets of engagement elements is controlled by a transmission control unit 90. The transmission control 90 unit may include sensors for determining the operational conditions of selector mechanisms 29,31,33 in the transmission. Typically these monitor the positions of the actuator members 48,58 and hence the positions of the sets of engagement elements, for example whether they are engaged with a gear wheel or not. The sensors can be included in the actuators 46,64, and may be, for example, Hall effect type sensors.

The transmission control unit is preferably in the form of an electronic logic control system driven by a processor, which runs software that is arranged to control operation of the first and second actuators 48,64 and hence the first and second sets of engagement elements 35,36. The sequence programming is typically arranged to control movement of the gear selector mechanisms 29,31a-d together with controlling the direction of torque in the transmission such that it prevents conflict shifts occurring. Being able to control the actuation of the first and second sets of engagement elements 35,36 totally independently by use of first and second actuators 46,64 has the advantage that the magnitude and the timing of application of the biasing force applied by each actuator can be independently controlled. This means that even at low rotational gear speeds the engagement elements sets 35,36 do not accidentally disengage from the engaged gear wheel and thus no loss of drive is experienced.

Figure 1c is a schematic diagram of a drive system including a transmission system 88 in accordance with the invention. The drive system includes an engine 80, an engine control unit 82, a sensor system 84 for determining the direction of torque in the transmission, a clutch device 86 such as a friction clutch, a transmission system 88, and the transmission control unit 90.

The engine 80 is typically an internal combustion engine in a vehicle but may be an electric motor for electric vehicles or any other suitable drive source. The output of the engine 80 is largely determined by the driver loading a throttle input device 81 (typically a throttle pedal), which is connected to the engine via a throttle interface 83 and the engine control unit 82. The engine control unit 82 is arranged to monitor and adjust the output of the engine 80 in accordance with instructions received from the user and the transmission control unit 90. The

engine control unit 82 may be a throttle potentiometer type system or alternatively an electronic control system (sometimes called a "drive by wire" system).

The engine control unit 82 communicates with the transmission control unit 90 via a Controller Area Network (CAN) bus.

- 5 The torque value in the transmission is determined in part by the output of the engine 80 and in part by the operational condition of the clutch 86, which determines the maximum permissible torque that can be transmitted to the transmission (clutch torque limit) according to the clamp load between the input and output sides of the clutch. The clamp load between the input and output sides of the clutch is determined by the transmission control unit 90 via
- 10 the clutch actuator 92. Reducing the clamp load between the clutch plates allows controlled relative rotational movement between the input and output sides of the clutch device 86 to control the value of torque transmitted. A typical value for speed difference can be 25rpm when operating around 4000rpm (4000rpm on one side of the clutch to 4025rpm on the other side).
- 15 The input and output clutch sensors 93 detect the speeds of the input and output sides of the clutch 86 respectively. The readings from the sensors 93 are monitored by the transmission control unit 90, which determines whether relative rotational movement is occurring and the direction of torque according to the values received from the sensors 93. The transmission control unit 90 is arranged to control the clutch actuator 92 and select the clutch clamp load in
- 20 order to transmit the desired amount of torque to the transmission 88.

The drive system may include one or more clutch clamp load sensors (not shown) in order to detect slip between the input and output sides of the clutch 86.

- The optional sensor system 84 for determining the direction of torque in the transmission, may include an accelerometer for determining whether the vehicle is accelerating or
- 25 decelerating such as a mercury switch, a pair of load cells arranged to detect strain in transmission components wherein from a comparison of the outputs of each load cell it is possible to determine the torque direction (see WO 2005/005869), a sensor for detecting throttle position and/or a sensor for determining the rate of change in velocity in a rotating transmission component, such as an output shaft. In each case, it is the transmission control
- 30 unit 90 that determines the direction of torque based on signals received from the sensor(s) used.

Any other suitable way of determining the direction of torque in the transmission can be used.

Optionally, the system can include a speed sensor 98 for detecting the output speed of the transmission. This can assist the transmission control unit 90 to determine which gear is engaged, since it can be programmed with details of the gear ratios and knows the input speed
5 from the output side of the clutch sensor 93. Also, the readings from the speed sensor 98 can be used by the transmission control unit 90 to take into account the effect of changing road conditions on the direction of torque in the transmission 88.

The operation of the first gear selector mechanism 29 will now be described with reference to Figures 5a-5e and 6 which for clarity illustrate diagrammatically the movement of the first
10 and second element sets 35,36 by the relative positions of only one element from each set.

Figure 5a shows the first and second engagement element sets 35,36 in a neutral position, that is, neither engagement element set is engaged with a gear wheel. Figure 5b shows the first and second engagement element sets moving into engagement with the gear A under the action of the first and second actuators 46,64 in response to a gearshift request from the input device 94
15 or the engine management system 82. Preferably, the clutch is opened for the first gear shift.

Figure 5c shows a condition when the gear A is fully engaged, that is, the engagement elements 28,30 are interleaved with the first and second sets of dogs 212,220. The first and second actuators 46,64 are arranged such that the actuator members 48,58 maintain the first and second engagement element sets 35,36 in engagement with the gear A. Accordingly,
20 drive is transferred through the gear A to the input shaft 3 via the first engagement element set 35 when decelerating and via the second engagement element set 36 when accelerating.

Whilst accelerating in gear A (rotating in the direction of arrow Y in Figure 5c), the engagement faces 43 of the engagement elements of the first engagement element set 35 are not loaded, whilst the engagement faces 43 of the engagement elements of the second element
25 set 36 are loaded. When a user, or the engine control unit 82, wishes to engage gear B an input signal is sent from the input device 94 or the engine control unit 82 to the processor. The processor instructs the transmission control unit to actuate the first actuator 46 to drive the first actuator member 48, which causes the engagement elements 28 of the first engagement element set 35 to slide axially along the keyways 41 in the sleeve 34 thereby
0 disengaging the first engagement element set 35 from the gear A (see Figure 5d).

The second actuator 64 is activated to move the second actuator member 58 and hence the second engagement element set 36 towards the gear B. However, because the second engagement element set 36 is loaded, i.e. is driving the gear A, it cannot be disengaged from the gear A, and the second engagement element set 36 remains stationary, with the second
5 actuator 64 biasing it towards the gear B.

When the first engagement element set 35 slides axially along the input shaft 3, the gear B is in the neutral position. In the neutral position the first set of dogs 212 is rotationally offset from the second set of dogs 222. The raised abutments 228 and the first set of dogs 212 are arranged to block full engagement of the second set of dogs 220. Each piston 240 is located
10 outside of its respective piston chambers 238, substantially centrally along its track 236, and each chamber 238 is substantially filled with hydraulic fluid. When the gear B is selected by the first engagement set the initial contact is with the end faces 42 on the upper surfaces 218,234 of the first set of dogs and the raised abutments. As the first set of engagement elements rotate relative to the gear B their engagement faces 43 subsequently engage the drive
15 faces 224 of the second set of dogs 220, which causes relative rotational movement between the outer and inner parts of the gear 202,204. The relative rotational movement causes the pistons 240 to move along their tracks 236 into the piston chambers 238 in the direction of torque applied by the selector mechanism 29. As each piston 240 moves into its respective piston chamber 238 the hydraulic fluid located in therein is pressurised, which causes some of
20 the hydraulic fluid to leak from the chamber 238. This action absorbs a significant proportion of the engagement energy thereby reducing the noise and shockwave of the impact and hence damps the engagement. The relative rotational movement between the inner and outer parts 204,202 of the gear wheel also loads the circlip 254.

When sufficient relative rotational movement has taken place to enable the first set of engagement elements 35 to move past the dogs 214 on the outer part 202 of the gear that
25 initially blocked axial movement, the first set of engagement elements 35 is able to move axially into the gaps between adjacent dogs 214 such that the drive faces 43 of the engagement elements 35 engage the drive faces 216 of the first set of dogs 212. Engaging the drive faces 216 of the first set of dogs prevents further relative rotation between the first and
30 second parts of the gear 204,202 (see Figure 5e). Thus the first set of dogs 212 now takes the driving load, which prevents the continued loading of the piston chambers 238. This

significantly increases the useful life of the gear element, while preserving its ability to reduce torque spikes.

When relative rotation is arrested, the engagement elements 28 drive the outer part 202 of the gear B in the direction of Arrow Z in Figure 5e and wherein drive is transmitted between the input and output shafts 3,1 via the second gear train 7. As this occurs, the second engagement element set 36 ceases to be loaded, and is free to disengage from the first group of dogs 212 on the gear A. Since the second engagement element set 36 is biased by the second actuator 64 it slides axially along the keyways 41 in the sleeve 34 thereby completing the disengagement of the gear A from the input shaft 3. The second engagement element set 36 slides along the keyways 41 until it engages the gear B, thereby completing engagement of the gear B with the input shaft 3.

This method of selecting gear trains substantially eliminates torque interruption since the gear train 7 B,C is engaged before the gear train A,D is disengaged, thus momentarily, the gears A,B are simultaneously engaged and locked for rotation with the input shaft 3, until the newly engaged gear wheel overdrives the original gear wheel. This type of gearshift is said to be instantaneous since a new gear is selected before the existing gear is released.

When a gear wheel is engaged by both the first and second engagement element sets 35,36 it is possible to accelerate or decelerate using a gear wheel pair with very little backlash occurring when switching between the two conditions. Backlash is the lost motion experienced when the dog moves from the engagement face 43 of the acceleration engagement element to the engagement face 43 of the deceleration engagement element when moving from acceleration to deceleration, or vice versa. A conventional dog-type transmission system has approximately 30 degrees of backlash. A typical transmission system for a car in accordance with the current invention has backlash of less than five degrees.

Backlash is reduced by minimising the clearance required between an engagement member and a dog during a gearshift: that is, the clearance between the dog and the following engagement member (see measurement X in Figure 5b). The clearance between the dog and the following engagement member is in the range 0.5mm - 0.03mm and is typically less than 0.2mm. Backlash is also a function of the retention angle, that is, the angle of the engagement face 43, which is the same as the angle of the undercut on the engagement face of the dog 20a. The retention angle influences whether there is relative movement between the dog and the

engagement face 43. The smaller the retention angle, the less backlash that is experienced. The retention angle is typically between 2.5 and 15 degrees.

Transition from the gear train B,D to the gear train A,D whilst decelerating is achieved by a similar process.

- 5 Whilst decelerating in the gear B the engagement surfaces 43 of the elements of the first element set 35 are not loaded, whilst the engagement surfaces 43 of the elements of the second element set 36 are loaded. When a user, or an engine control unit wants to engage the first gear train 5 a signal is sent from the input device or the engine control unit to the processor. The processor instructs the transmission control unit to actuate the first actuator 46
10 to move the first actuator member 48 axially, causing the first engagement element set 35 to slide axially in the keyways 41 along the input shaft 3 in the direction of the gear A, thereby disengaging the first engagement element set 35 from the gear B.

The transmission control system activates the second actuator 64 however 60 since the second engagement element set 36 is loaded, i.e. it is drivingly engaged with the dogs 212,220 on the
15 gear B, it remains stationary but is urged towards the gear A.

As the first engagement element set 35 slides axially in the keyways 41 the gear A is in the neutral position. In the neutral position the first set of dogs 212 is rotationally offset from the second set of dogs 222. The raised abutments 228 and the first set of dogs 212 are arranged to block full engagement of the second set of dogs 220. Each piston 240 is located outside of its
20 respective piston chambers 238, substantially centrally along its track 236, and each chamber 238 is substantially filled with hydraulic fluid. When the gear A is selected by the first engagement set the initial contact is with the end faces 42 on the upper surfaces 218,234 of the first set of dogs and the raised abutments. As the first set of engagement elements 35 rotates relative to the gear A its engagement faces 43 subsequently engage the drive faces 224
25 of the second set of dogs 220, which causes relative rotational movement between the outer and inner parts of the gear 202,204. The relative rotational movement causes the pistons 240 to move along their tracks 236 into the piston chambers 238 in the direction of torque applied by the selector mechanism 29. As each piston 240 moves into its respective piston chamber 238 the hydraulic fluid located therein is pressurised, which causes some of the hydraulic
30 fluid to leak from the chamber 238. This action absorbs a significant proportion of the engagement energy thereby reducing the noise and shockwave of the impact and hence damps

the engagement. The relative rotational movement between the inner and outer parts 204,202 of the gear wheel also loads the circlip 254.

When sufficient relative rotational movement has taken place to enable the first set of engagement elements 35 to move past the dogs 214 on the outer part 202 of the gear that initially blocked axial movement, the first set of engagement elements 35 is able to move axially into the gaps between adjacent dogs 214 such that the drive faces 43 of the engagement elements 35 engage the drive faces 216 of the first set of dogs 212. Engaging the drive faces 216 of the first set of dogs prevents further relative rotation between the first and second parts of the gear 204,202 (see Figure 5e). Thus the first set of dogs 212 now takes the driving load, which prevents the continued loading of the piston chambers 238. Thus energy is transmitted between the input and second lay shaft 3,6 by way of the gear train A,D.

As this occurs, the second engagement element set 36 ceases to be loaded and biasing of the second actuator 64 causes it to slide axially within the keyways 41 along the input shaft 3 towards the gear A, thereby completing disengagement of the gear B. The second engagement element set 36 continues to slide within the keyways 41 along the input shaft 3 until it engages the gear A, thereby completing locking engagement of the gear A with the input shaft 3.

Kick-down shifts, that is a gearshift from a higher gear train to a lower gear train but where acceleration takes place, for example when a vehicle is travelling up a hill and the driver selects a lower gear to accelerate up the hill, require a brief torque interruption to allow disengagement of the driving element set. For example, when accelerating in gear B, gear B is fully engaged by the first and second sets of engagement elements 35,36 and the first element set 35 drivingly engages the dogs. When a kick-down shift is requested by the user via the input device 94 or the engine control unit 82, the transmission control unit 90 reduces the clutch clamp load using the clutch actuator 92 until controlled relative rotational movement between the input and output sides of the clutch is detected by the transmission control unit 90 via the clutch sensor 93 readings. The engine speed is then adjusted to synchronise with the new gear speed, which typically involves increasing the engine speed. The transmission control unit 90 is able to synchronise the speed since it is programmed with information relating to the gear ratios for each gear train and can determine the currently engaged gear and the new gear to be selected. Synchronising the engine speed in this manner has a smoothing effect when engaging the new gear and prevents the vehicle from lurching when the gear is

selected. The clutch clamp load is then further reduced as is the throttle in order to maintain the new ratio speed. The loaded 35 and the unloaded element sets 36 are then disengaged from the gear B by actuating the first and second actuators 46,64 such that loaded set disengages the gear B prior to the unloaded set 36 engaging the gear A. The torque spike
5 caused by the engagement is minimised due to the speed synchronisation step. However if a torque spike is generated its effect is mitigated by further relative rotation of the input and output sides of the clutch 86. In practice it is preferable to reduce the torque transmittable by the clutch to zero, or near zero, or at least sufficiently low such that the actuators 46,64 are able to move the sets of engagement before disengaging the loaded set of engagement
10 elements 35. Although the shift is not entirely instantaneous, it is very quick and the power interruption is lower than previous methods and may not even be noticed by the driver. The torque is reinstated by the engine control unit 82, the clutch clamp load is restored by the clutch actuator 92 and control of the engine 80 is returned to the user.

When the unloaded second element set 36 is disengaged from the gear B, it can alternatively
15 be held in the neutral position until after the loaded first element set 35 is disengaged from the gear B. The second element set 36 can then be moved into engagement with the gear A, after which the torque and clutch are reinstated. This shift is not instantaneous.

Torque paths

Power enters the transmission 88 through the input shaft 3 and is transferred to the first and
20 second lay shafts 4,6 according to the operational status of the selector mechanism 29. Drive is transferred to the output shaft 1 from the first and second lay shafts 4,6 according to the operational status of the synchromesh selector mechanisms 31a-d.

The transmission control unit 90 is arranged to preselect the gears E,H,J,K,L,M that are mounted on the lay shafts 4,6 by controlling the operation of the selector mechanisms 31a-d.
25 Then by controlling the operation of the instantaneous selector mechanism 29, for example by alternately selecting the gears A and B on the input shaft 3, the transmission system can perform instantaneous shifts for each gear ratio, for at least some shift types, using only a single instantaneous selector mechanism 29. For example, the torque path for first gear with reference to Figure 1a is B,C,E,F, that is the selector mechanism 29 locks gear B for rotation
30 with the input shaft 3, the synchromesh selector mechanism 31a locks gear E for rotation with the first lay shaft 4 and drive is transmitted to the output shaft via gear F. When there is a call

for second gear, either by the engine management system 82 or user of the vehicle, the transmission control unit preselects gear K with the synchromesh selector mechanism 31b and then locks gear A for rotation with the input shaft 3 in an instantaneous manner, for example see the description relating to accelerating up shifts and decelerating down shifts above. When the gear A is fully selected by the selector mechanism 29, drive then flows to the output shaft 1 via gears A,D,K,F. When there is a call for third gear, the transmission control unit 90 preselects gear H with the synchromesh selector mechanism 31a, and then locks gear B for rotation with the input shaft 3 in an instantaneous manner with the selector mechanism 29. When the gear B is fully selected by the selector mechanism 29, drive then flows to the output shaft via gears B,C,H,G. Fourth gear can be selected by preselecting gear L with selector mechanism 31b and selecting gear A with selector mechanism 29, provided by torque path A,D,L,G. Fifth gear is provided by torque path B,C,J,I and sixth gear by torque path A,D,M,I.

It will be appreciated by the skilled person that this is reversible and that instantaneous downshifts can be performed, for example by moving from sixth gear A,D,M,I to fifth gear B,C,J,I by preselecting gear J and subsequently selecting gear B.

Thus the transmission system is sequential and can provide instantaneous shifts between the current gear and the previous gear, and the current gear and the subsequent gear, for at least some shift types by preselecting the gears E,H,J,K,L,M mounted on the first and second lay shafts 5,6 and alternately selecting gears A and B with the instantaneous selector mechanism 29.

A transmission system arranged in this manner is compact in length, which is highly advantageous for front wheel drive applications. It provides for a significant amount of space for gears A and B to be relatively large in size to accommodate sufficiently large damping mechanisms 200 to accommodate the significant loads experienced during use. It also avoids the lockup problem described in the introductory paragraphs since all instantaneous shifts are achieved by moving a single instantaneous selector mechanism 29, which is inherently safe. The lockup problem only occurs when it is necessary to operate more than one instantaneous selector mechanism during a shift. Furthermore, using conventional non-instantaneous selector mechanisms to preselect the gears mounted on the lay shafts 4,6 significantly simplifies the control capabilities required by the transmission control unit 90 since it is significantly easier to control engagement of a gear element with, for example a conventional synchromesh selector mechanism than it is an instantaneous mechanism 29. Also,

instantaneous selector mechanisms typically require damped gears, or some other damping system, in order to meet Noise, Vibration and Harshness (NVH) standards, therefore replacing instantaneous mechanisms with conventional synchromesh selector mechanisms obviates the need to damp all of the gears in the transmissions, which saves on space and cost,
5 while still providing instantaneous shifts for each ratio.

The layout also provides the possibility of modularity, that is, it is easy to add additional gear trains to provide additional gear ratios and also multiple path ways without increasing the number of gear trains, as can be seen from the additional embodiments below.

Further compactness can be achieved by offsetting the input and output shafts in Z axis, for
10 example to provide a substantially triangular arrangement when the shafts are viewed end on.

A second transmission layout is shown in Figures 6a and 6b. The second embodiment is similar to the first embodiment in that it comprises a single instantaneous selector mechanism 329 mounted on an input shaft 303 and conventional synchromesh selector mechanisms 331a-d mounted on the first and second lay shafts 304,306, that are arranged to create torque paths
15 between the input shaft 303 and an output shaft 301 via gears A',B',C',D',E',F',G',H',I',J', and to make instantaneous shifts for each gear ratio for at least some shift types.

The gear trains are arranged as follows: a first gear train 308 including a gear A' mounted on the input shaft 303 via a bearing so that it can rotate relative to the input shaft 303, a gear C' mounted on the first lay shaft 304 via a bearing so that it can rotate relative to the first lay
20 shaft 304 and a gear E' mounted on the second lay shaft 306 via a bearing so that it can rotate relative to the second lay shaft 306; a second gear train 310 including a gear B' mounted on the input shaft 303 via a bearing so that it can rotate relative to the input shaft 303, and a gear D' mounted on the first lay shaft 304 via a bearing so that it can rotate relative to the first lay shaft 304 and a gear F' mounted on the second lay shaft 306 via a bearing so that it can rotate
25 relative to the second lay shaft 306; a third gear train 312 including a gear G' mounted on the first lay shaft 304 via a bearing so that it can rotate relative to the first lay shaft 304, a gear K' mounted on the output shaft 301 so that it rotates with the output shaft 301 and a gear I' mounted on the second lay shaft 306 via a bearing so that it can rotate relative to the second lay shaft 306; and a fourth gear train 314 including a gear H' mounted on the first lay shaft
30 304 via a bearing so that it can rotate relative to the first lay shaft 304, a gear L' mounted on

the output shaft 301 so that it rotates with the output shaft 301 and a gear J' mounted on the second lay shaft 306 via a bearing so that it can rotate relative to the second lay shaft 306.

5 The first and second lay shafts 304,306 are arranged substantially parallel with the input shaft 303 and are further arranged such that the distance X between the longitudinal axis of the input shaft 303 and the longitudinal axis of the first lay shaft 304 is different from the distance Y between the longitudinal axis of the input shaft 303 and the longitudinal axis of the second lay shaft 306. This because the first gear train 308 includes the gear A' mounted on the input shaft 303 that provides a torque path A',C' with the first lay shaft 304 and a second torque path A',E' with the second lay shaft 306. In order to provide a variety of different gear ratios within the transmission system it is highly desirable to provide different gear ratios for the torque paths A',C' and A',E' and therefore the diameter of the gears C' and E' will be different thus providing the different distances between longitudinal axes. This is also the case for the second gear train 310. Having the transmission system arranged in this manner helps to provide a highly compact arrangement with multiple torque paths. Furthermore, the gear ratios in this arrangement are typically in the form of a geometric spread.

It can be seen in Figures 6a and 6b that the input and output shafts 303,301 do not overlap longitudinally. The output shaft 301 starts substantially when the input shaft 303 ends. It can also be seen that the first and second lay shafts 304,306 run substantially the full length of the transmission casing 302 and are supported at each end by bearings. Preferably the casing 302 includes an internal partition 302a that includes bearings for supporting the first and second lay shafts 304,306 and the input and output shafts 303,301. The gears A',B',C',D',E',F' on the input side of the transmission are on one side of the partition 302a and the gears G',H',I',J',K',L' from the output side are on the other side of the partition 302a.

25 The input and output shafts 303,301 are offset co-axially in Figures 6a and 6b, that is in the direction into the plane of the Figures. So if the Figures define the X-Y plane, the output shaft 301 is offset from the input shaft 303 in at least the Z axis. The shafts can be arranged such that the input and output shafts 303,301 are offset in at least one of the three axis. When looking end on at the shafts, the input and output shafts 303,301 are thus centrally offset, for example in a diamond or arrowhead shaped configuration.

An instantaneous gear selector mechanism 329 is mounted on the input shaft 303 between the gears A' and B' and is arranged to selectively lock the gears A' and B' for rotation with the input shaft 303 in a manner described above for the first embodiment.

A first synchromesh selector mechanism 331a is mounted on the first lay shaft 304 between the gears C' and D' and is arranged to selectively lock the gears C' and D' for rotation with the first lay shaft 304 independently of each other. The first synchromesh selector mechanism is of the split type. Using a split selector mechanism 331a means that both gear C' and gear D' can be locked for rotation with the first lay shaft 304 simultaneously. A second synchromesh selector mechanism 331b is mounted on the second lay shaft 306 between the gears E' and F' and is arranged to selectively lock the gears E' and F' for rotation with the second lay shaft 306. The second selector mechanism 331b is also of the split type so that gears E' and F' can be selectively locked for rotation with the second lay shaft 306 independently of each other.

A third synchromesh selector mechanism 331c is mounted on the first lay shaft 304 between gears G' and H' and is arranged to selectively lock gears G' and H' for rotation with the first lay shaft 304. The third selector mechanism 331c is of the conventional type that can only lock either gear G' or H' for rotation with the first lay shaft 304 at any one time. A fourth synchromesh selector mechanism 331d is mounted on the second lay shaft 306 between gears I' and J' and is arranged to selectively lock gears I' and J' for rotation with the second lay shaft 306. The fourth selector mechanism 331d is of the conventional type that can only lock either gear I' or J' for rotation with the second lay shaft 306 at any one time.

A significant advantage of the second embodiment is that it can either be used as an eight-speed transmission or a sixteen-speed transmission. Table 1 below illustrates the torque paths for each gear ratio.

Gear	Torque Path
1	A',C',G',K'
2	B',D',G',K'
3	A',E',I',K'
4	B',F',I',K'
5	A',C',H',L'
6	B',D',H',L'
7	A',E',J',L'
8	B',F',J',L'

9	A',E',F',B',D',G',K'
10	B',F',E',A',C',G',K'
11	A',E',F',B',D',H',L'
12	B',F',E',A',C',H',L'
13	A',C',D',B',F',I',K'
14	B',D',C',A',E',I',K'
15	A',C',D',B',F',J',L'
16	B',D',C',A',E',J',L'

Table 1

By adding another gear train it is possible to provide twelve or twenty-four gear ratios as required.

Figures 7a and 7b show a variant of the second embodiment. The variant is similar to the second embodiment except that the first synchromesh selector mechanism 331a is not of the split type, but rather is of the conventional type that selects either gear C' or D' at any one time.

Table 2 below illustrates one possible set of torque paths for each gear ratio.

Gear	Torque Path
1	A',C',G',K'
2	B',F',I',K'
3	A',C',H',L'
4	B',F',J',L'
5	A',E',I',K' [AMT]
6	B',D',G',K'
7	A',E',J',L'
8	B',D',H',L'

Table 2

Table 3 below illustrates another possible set of torque paths for each gear ratio.

Gear	Torque Path
1	A',C',G',K'
2	B',F',J',L'
3	A',C',H',L'
4	B',F',I',K'
5	A',E',I',K'
6	B',D',G',K'
7	A',E',F',B',D',G',K'
8	B',D',H',L' [AMT]

Table 3

In Tables 2 and 3, [AMT] represents a non-instantaneous shift. It is preferable to have this type of shift in the upper gears as illustrated in Table 3, when moving from seventh to eighth gear.

5 It will be appreciated by the skilled person that the invention is not to be considered as strictly limited to the above embodiment and that modifications can be made that fall within the scope of the invention, for example the number of gear trains included and the specific type of selector assemblies used. Instead of using synchromesh assemblies on the first and second lay shafts conventional dog shift mechanisms or instantaneous selector mechanisms similar to mechanism 29 can be used, though this increases the complexity of the transmission control
10 unit.

Alternatively, or additionally, to having an instantaneous selector mechanism mounted on the input shaft 3 it can be mounted on the output shaft 1, together with the rotatably mounted gears. This is less desirable than mounting on the input shaft 3 since it adds the inertia of the gears and lay shafts 4,6 to the shifting actions, however the concept falls within the scope of
15 the invention.

Claims

1. A transmission system including first, second, third and fourth shafts, wherein the second and third shafts are lay shafts; a first gear train for transmitting drive between the first and second shafts including a first gear element rotatably mounted on the first shaft and a second gear element mounted on the second shaft; a second gear train for transmitting drive between the first and third shafts including a third gear element rotatably mounted on the first shaft and a fourth gear element mounted on the third shaft; a third gear train for transmitting drive between the second and fourth shafts and/or the third and fourth shafts; a first selector assembly arranged to selectively lock each of the first and third gear elements for rotation with the first shaft from operational modes that include the following modes: lock the gear element for rotation with the first shaft in the clockwise and anti-clockwise directions; lock the gear element for rotation with the first shaft in the clockwise direction and not lock in the anti-clockwise direction; and lock the gear element for rotation with the first shaft in the anti-clockwise direction and not lock in the clockwise direction; and damping means for damping engagement of the first and third gear wheels by the first selector assembly.
2. A transmission system according to claim 1, wherein the first shaft is an input shaft and the second shaft is an output shaft.
3. A transmission system according to claim 1 or 2, wherein the third gear train includes a fifth gear element rotatably mounted on the second shaft and a sixth gear element mounted on the fourth shaft, and the transmission system includes a second selector assembly arranged to selectively lock the fifth gear element for rotation with the second shaft.
4. A transmission system according to claim 3, wherein the third gear train includes a seventh gear element rotatably mounted on the third shaft, and the transmission system includes a third selector assembly arranged to selectively lock the seventh gear element for rotation with the third shaft.
5. A transmission system according to any one of the preceding claims, wherein the first gear train is arranged to transfer drive between the first and third shafts and includes an eighth gear element rotatably mounted on the third shaft, the fourth gear element is rotatably mounted on the third shaft and the transmission system includes a fourth gear selector assembly for selectively locking the fourth and eighth gear elements for rotation with the third shaft.

6. A transmission system according to claim 3, wherein the fourth selector assembly is arranged to selectively engage the fourth and eighth gear elements from operational modes that include the following operational modes: lock the fourth gear element for rotation with the third shaft and not lock the eighth gear element; lock the eighth gear element for rotation with the third shaft and not lock the fourth gear element; and lock both the fourth and the eighth gear elements for rotation with the third shaft.
7. A transmission system according to any one of the preceding claims, wherein the second gear train is arranged to transfer drive between the first and second shafts and includes a ninth gear element rotatably mounted on the second shaft, the second gear element is rotatably mounted on the second shaft and the transmission system includes a fifth gear selector assembly for selectively locking the second and ninth gear elements for rotation with the second shaft.
8. A transmission system according to claim 5, wherein the fifth selector assembly is arranged to selectively engage the second and ninth gear elements from operational modes that include the following operational modes: lock the second gear element for rotation with the second shaft and not lock the ninth gear element; lock the ninth gear element for rotation with the second shaft and not lock the second gear element; and lock both the second and the ninth gear elements for rotation with the second shaft.
9. A transmission system according to any one of the preceding claims, including a fourth gear train including an eleventh gear element mounted on the fourth shaft and a twelfth gear element rotatably mounted on the third shaft, and wherein the third selector assembly is arranged to selectively lock the twelfth gear element for rotation with the third shaft.
10. A transmission system according to claim 8, wherein the fourth gear train includes a tenth gear element rotatably mounted on the second shaft, and the second selector assembly is arranged to selectively lock the tenth gear element for rotation with the second shaft.
11. A transmission system according to any one of the preceding claims, including a fifth gear train including a thirteenth gear element rotatably mounted on the second shaft, a fourteenth gear element mounted on the fourth shaft and a fifteenth gear element rotatably mounted on the third shaft, and a sixth selector assembly arranged to selectively lock the thirteenth gear element for rotation with the second shaft and a seventh selector assembly arranged to selectively lock the fifteenth gear element for rotation with the third shaft.

12. A transmission system according to any one of the preceding claims, wherein the second, third, fourth and fifth selector assemblies are non-instantaneous selector assemblies such as of the synchromesh or dog type selector assemblies.
13. A transmission system according to any one of the preceding claims, wherein the first selector assembly includes first and second sets of engagement members that are arranged to selectively lock the first gear element for rotation with the first shaft and each of the first and third gear elements includes first and second parts that are arranged to rotate relative to each other and a damping system for damping the relative rotational movement.
14. A transmission system according to claim 12, wherein the first part includes a first set of drive formations, the second part includes a second set of drive formations, and when selecting the gear element with one of the first and second sets of engagement members, that set of engagement members is arranged to drivingly engage the second set of drive formations to cause relative rotational movement between the first and second parts of the gear element, the damping system is arranged to damp the relative rotational movement between the first and second parts of the gear element, and after some damping has occurred the engagement members are arranged to drivingly engage the first set of drive formations.
15. A transmission system according to any one of the preceding claims, wherein the first selector assembly is arranged to select one of the first and third gear elements while the other of the first and third gear elements is still engaged by the selector assembly.
16. A transmission system according to any one of claims 12 to 14, wherein the selector assembly is arranged such that when a driving force is transmitted, one of the first and second sets of engagement members drivingly engages the engaged gear element, and the other set of engagement members is then in an unloaded condition.
17. A transmission system according to claim 15, wherein the selector assembly is arranged such that when a braking force is transmitted the first set of engagement members drivingly engages the engaged gear element, and the second set of engagement members is in an unloaded condition, and when a driving force is transmitted the second set of engagement members drivingly engages the engaged gear element, and the second set of engagement members is then in an unloaded condition.

18. A transmission system according to any one of claims 12 to 16, wherein the damping system is arranged to allow lost motion between the first shaft and at least one of the first gear element and the first selector assembly after the selector assembly engages the first gear element.
19. A transmission system according to any one of claims 12 to 17, wherein the damping system is a fluid damping system, and preferably a hydraulic damping system.
20. A transmission system according to claim 18, including first and second piston chambers located in the second part of the gear element and a first piston that is arranged to move with the first part of the gear element and to move into and out of the first and second piston chambers according to the relative rotational movement of the first and second parts of the gear element.
21. A transmission system according to claim 19, including third and fourth piston chambers located in the second part of the gear element and a second piston that is arranged to move with the first part of the gear element and to move into and out of the third and fourth piston chambers according to the relative rotational movement of the first and second parts of the gear element.
22. A transmission system according to claim 19 or 20, wherein the first and second pistons and each of their respective piston chambers are arranged to allow hydraulic fluid to leak from the chambers during a damping action.
23. A transmission system according to any one of claims 12 to 21, wherein one of the first and second parts of the gear element includes meshing means for meshing with another gear element, and the other of the first and second parts of the gear element includes means for mounting the gear element on a shaft.
24. A transmission system according to any one of claims 12 to 22, wherein when the first and second parts of the gear element are fitted together, the first and second sets of drive formations are located on the same side face.
25. A transmission system according to any one of claims 12 to 23, wherein the first set of drive formations includes n drive formations, wherein n is in the range 2 to 24, preferably 3 to 16 and more preferably 3 to 6.

26. A transmission system according to any one of claims 12 to 24, wherein the second set of drive formations includes n drive formations, wherein n is in the range 2 to 10, preferably 3 to 6.
27. A transmission system according to any one of claims 12 to 25, including means for limiting the axial movement of the first and second sets of engagement members.
28. A transmission system according to claim 26, wherein the means for limiting the axial movement of the first and second sets of engagement members includes at least one of: a set of raised abutments, wherein the raised abutments are located on the second part of the gear element and are arranged alternately with the drive formations in the second set of drive formations; and the first set of drive formations, the depth dimension being selected to determine the extent of axial limitation of the first and second sets of engagement members.
29. A transmission system according to any one of claims 12 to 27, wherein the drive formations in the first set of drive formations are distributed on the first part of the gear element such that they are substantially equally angularly spaced.
30. A transmission system according to any one of claims 12 to 28, wherein the drive formations in the second set of drive formations are distributed on the second part of the gear element such that they are substantially equally angularly spaced.
31. A transmission system according to any one of claims 12 to 29, including means for self-centring the relative rotational orientations of the first and second parts of the gear element.
32. A transmission system according to claim 30, wherein the means for self-centring includes resilient means, such as a spring element.
33. A transmission system according to claim 30 or 31, wherein, when in an unloaded condition, the drive formations of the first set of drive formations are rotationally offset from the drive formations in the second set of drive formations.
34. A transmission system according to any one of claims 30 to 32, wherein, when in an unloaded condition, the drive formations of the first set of drive formations are rotationally aligned with the drive formations in the second set of drive formations.

35. A transmission system according to any one of claims 18 to 33, wherein the damping fluid is supplied to the interior of the gear element via the first shaft.
36. A transmission system according to any one of the preceding claims, wherein the first gear selector assembly is arranged to select the following operational mode with respect to the first gear element: the first gear element is not locked for rotation with the first shaft in the clockwise or anticlockwise directions.
37. A transmission system according to any one of the preceding claims, including an electronically programmable control system for controlling operation of the or each gear selector assembly.
38. A transmission system according to claim 36, wherein the control system is arranged to control the operation of the or each selector mechanism to perform sequential gear shifts.
39. A transmission system according to claim 36 or 37, wherein the control system is arranged to bias the loaded set of engagement members towards the unengaged gear wheel until the loaded set of engagement members are free to move.
40. A transmission system according to any one of the preceding claims, including means for determining the direction of torque in the transmission system when receiving a request for a gearshift.
41. A transmission system according to any one of the preceding claims, including means for preventing the direction of torque in the transmission changing during a gearshift.
42. A transmission system including first, second, third and fourth shafts, wherein the second and third shafts are lay shafts; a first gear train for transmitting drive between the first and second shafts including a first gear element rotatably mounted on the first shaft and a second gear element mounted on the second shaft; a second gear train for transmitting drive between the first and third shafts including a third gear element rotatably mounted on the first shaft and a fourth gear element mounted on the third shaft; a third gear train for transmitting drive between the second and fourth shafts and/or the third and fourth shafts; a first gear selector assembly for selectively transmitting torque between the first shaft and the first gear element and between the first shaft and the third gear element, said first selector assembly including first and second sets of engagement members that are moveable into and out of engagement with the first and third gear elements and an actuator system for actuating the

engagement members, wherein the first gear selector assembly is arranged such that when a driving force is transmitted, one of the first and second sets of engagement members drivingly engages the engaged gear element, and the other set of engagement members is then in an unloaded condition and the actuator system is arranged to move the unloaded set of engagement members into driving engagement with the unengaged gear element to effect a gear change, damping means for damping engagement of the first and third gear wheels by the first selector assembly, and a second selector assembly arranged to selectively lock the fifth gear element for rotation with the second shaft.

43. A transmission system according to claim 41, wherein the third gear train includes a seventh gear element rotatably mounted on the third shaft and the transmission system includes a third selector assembly arranged to selectively lock the seventh gear element for rotation with the third shaft.
44. A transmission system according to claim 41 or 42, wherein the first selector assembly is such that when a braking force is transmitted the first set of engagement members drivingly engages the engaged gear wheel, and the second set of engagement members is in an unloaded condition, and when a driving force is transmitted the second set of engagement members drivingly engages the engaged gear wheel, and the first set of engagement members is then in an unloaded condition.
45. A transmission system according to any one of claims 12 to 43, including an actuator system for the first selector assembly that includes a first actuator device for actuating the first set of engagement members and a second actuator device for actuating the second set of engagement members independently of the first actuator device.
46. A transmission system according to any one of claims 12 to 44, the first selector assembly is arranged such that when the first and second sets of engagement members engage one of the first and second gear elements the backlash when moving between acceleration and deceleration is less than or equal to five degrees.
47. A transmission system according to claim 45, arranged according to any one of claims 12 to 40.

48. A transmission system according to any one of the preceding claims, wherein the selector assembly is operated to select alternately the first and third gear elements when shifting between gear ratios.
49. A transmission system according to any one of the preceding claims, wherein the first and second lay shafts are arranged substantially parallel to the input shaft and the distance between the longitudinal axis of the input shaft and the longitudinal axis of the first lay shaft is different from the distance between the longitudinal axis of the input shaft and the longitudinal axis of the second lay shaft.
50. A transmission system according to any one of the preceding claims, wherein the output shaft is arranged substantially parallel to the input shaft and the longitudinal axis of the output shaft is offset from the longitudinal axis of the input shaft such that the input shaft and the output shaft are not co-axial.
51. A transmission system according to any one of the preceding claims, wherein the gear trains are arranged in the form of a geometric spread

TORQUE PATHS

BCEF
ADKF
BCHG
ADLG
BCJI
ADMI

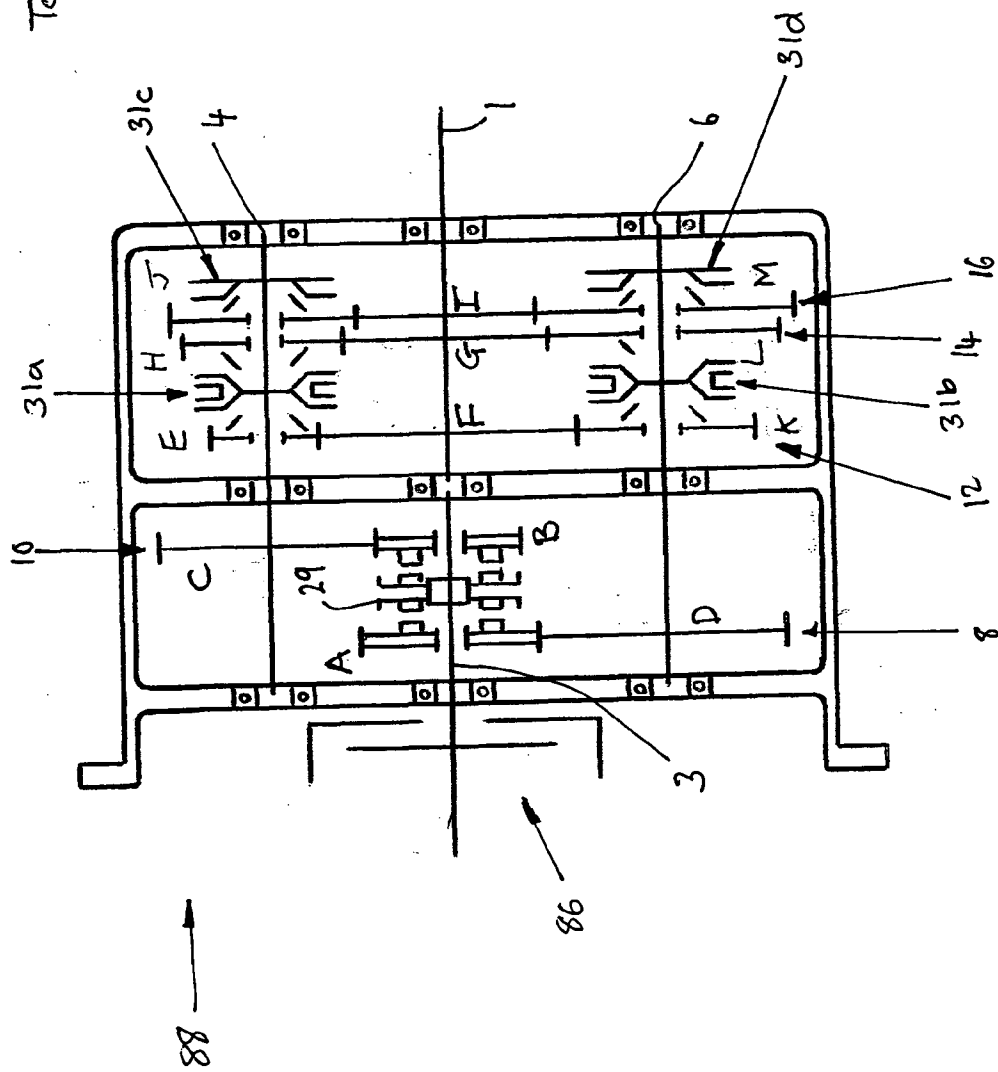
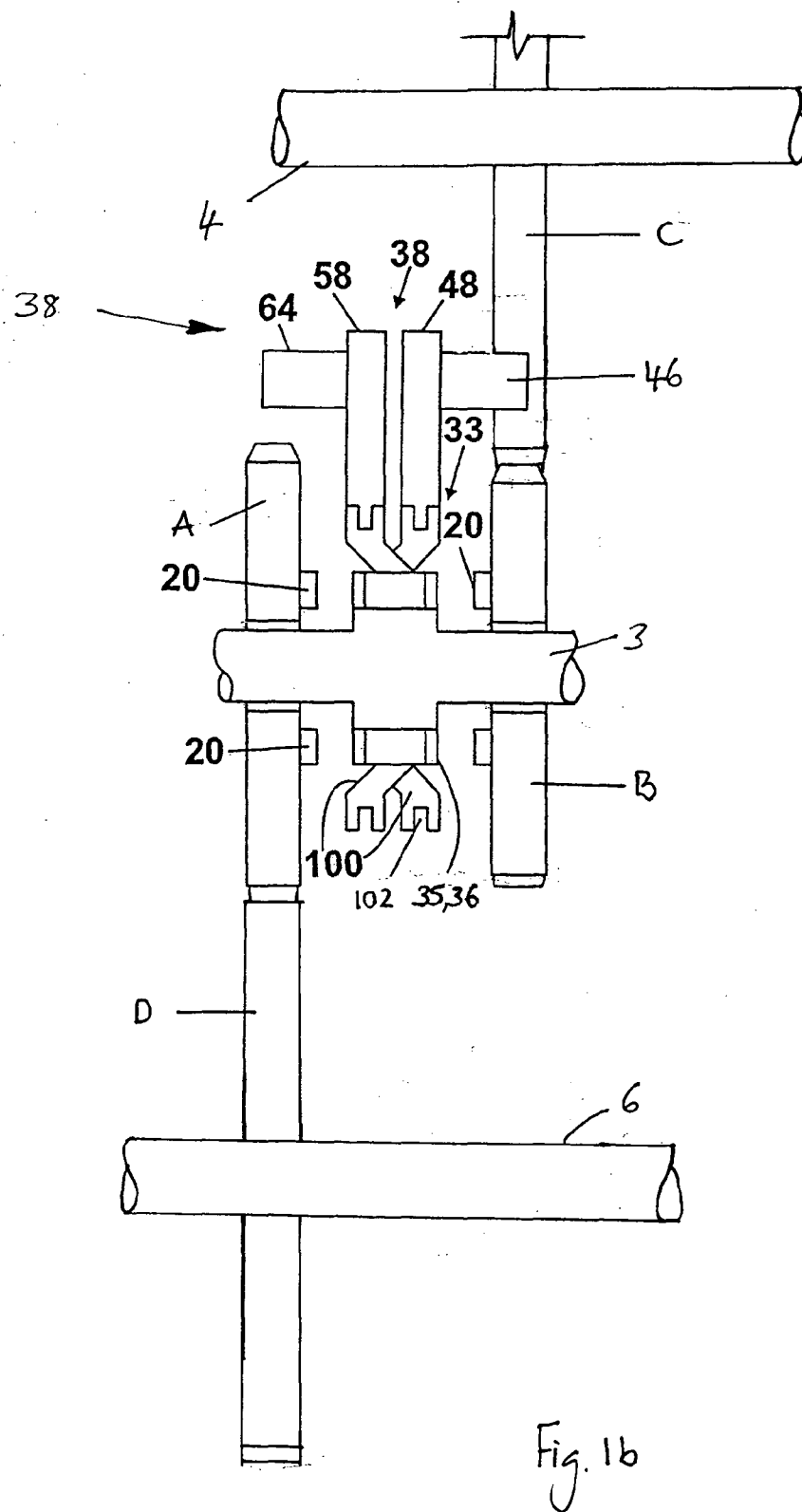
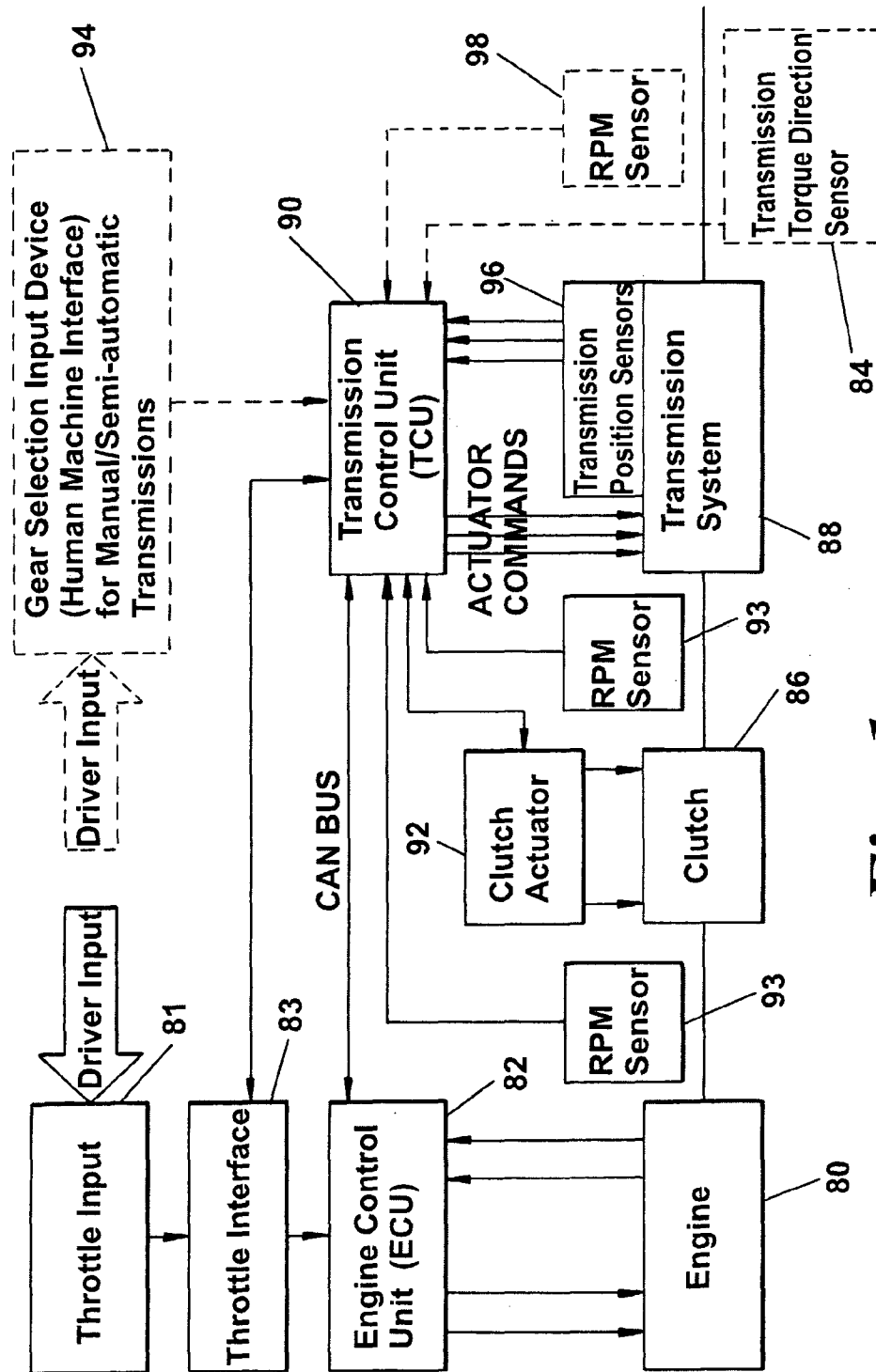


Fig. 1a



*Fig. 1c*

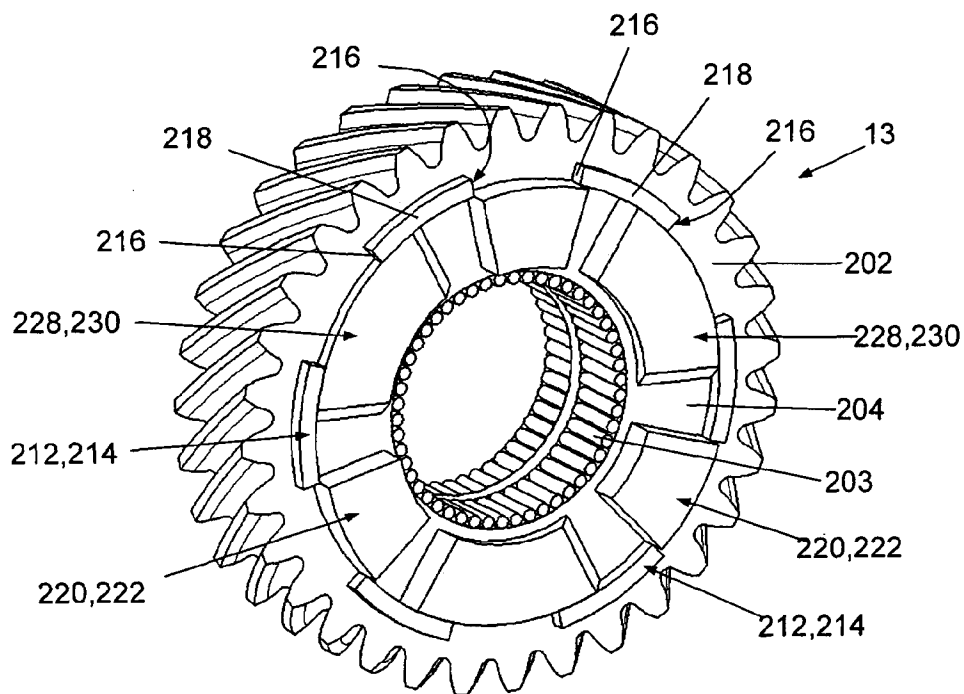


Fig. 2a

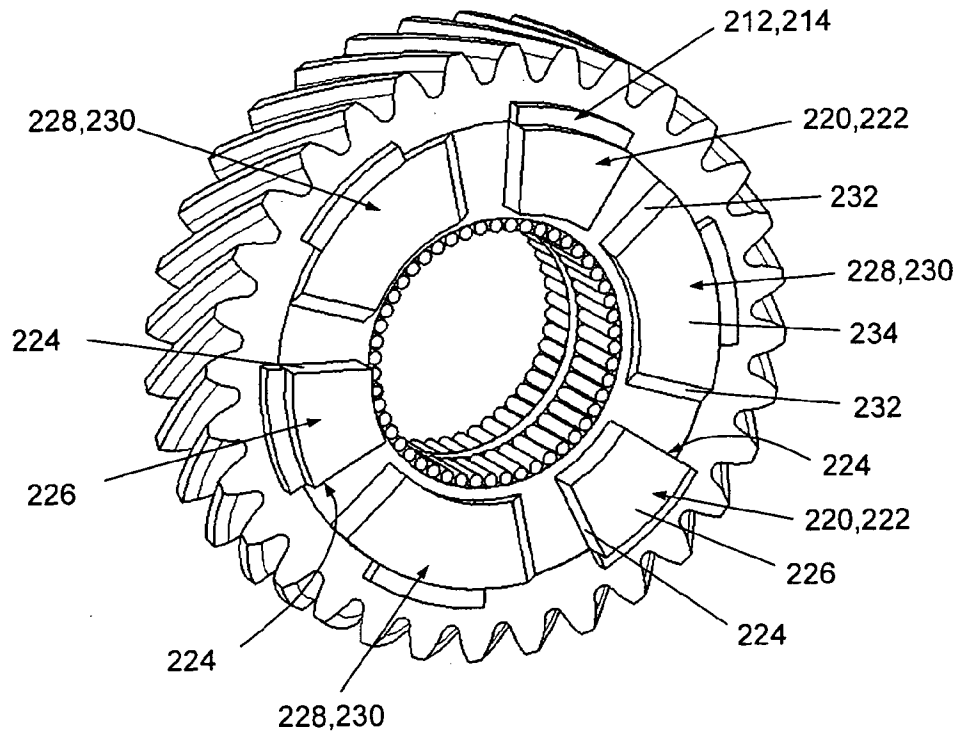


Fig. 2b

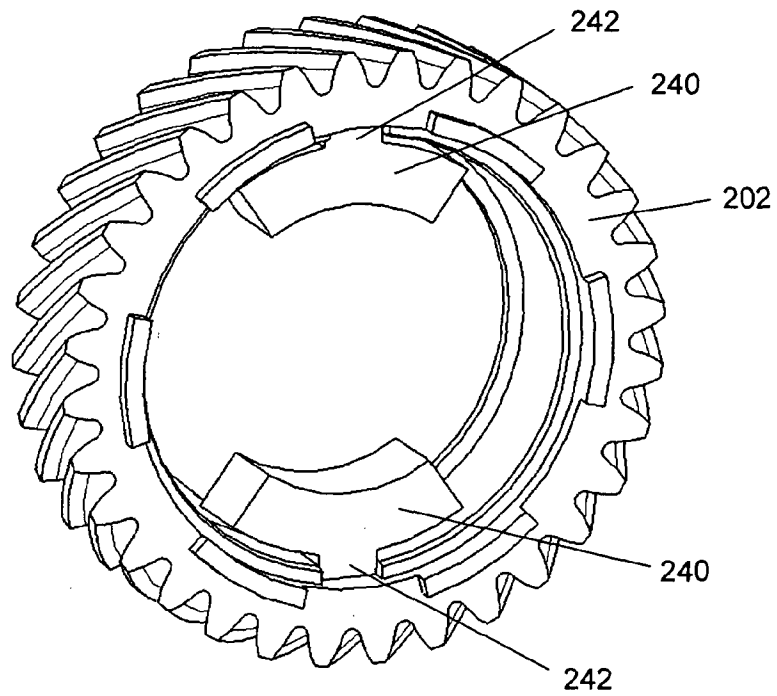


Fig. 2c

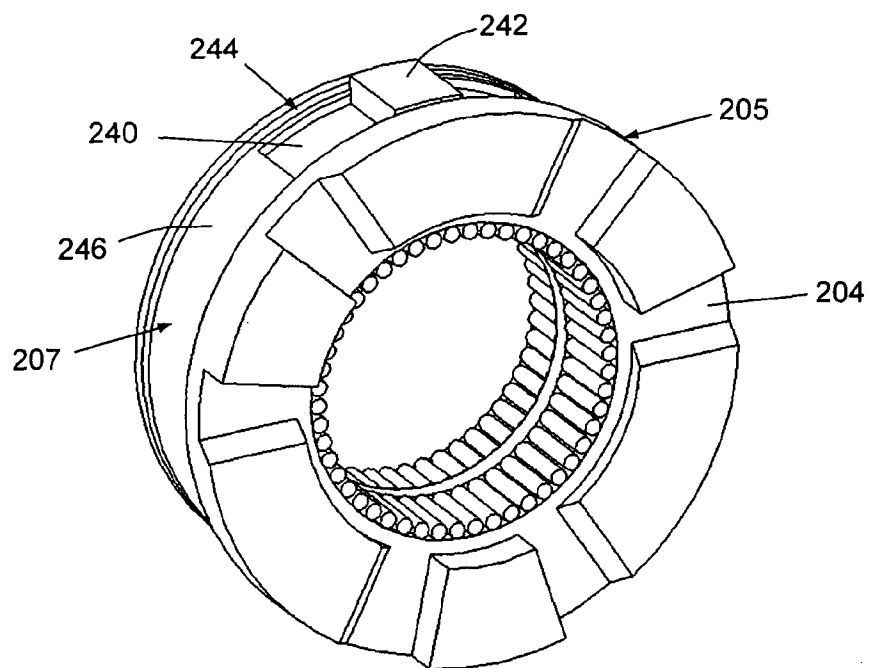


Fig. 2d

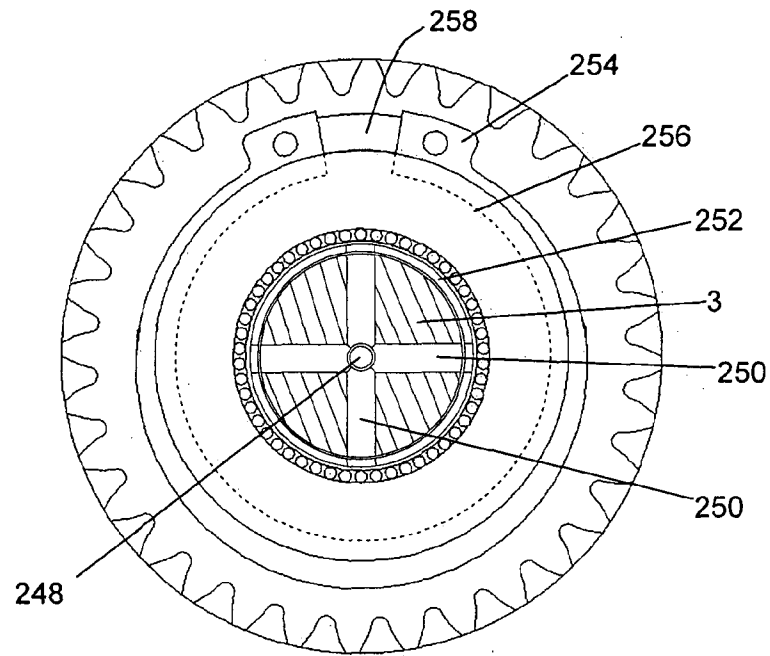


Fig. 2e

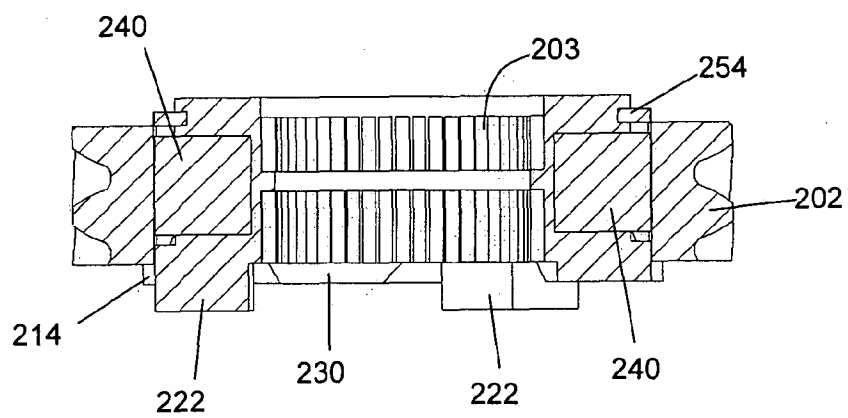


Fig. 2f

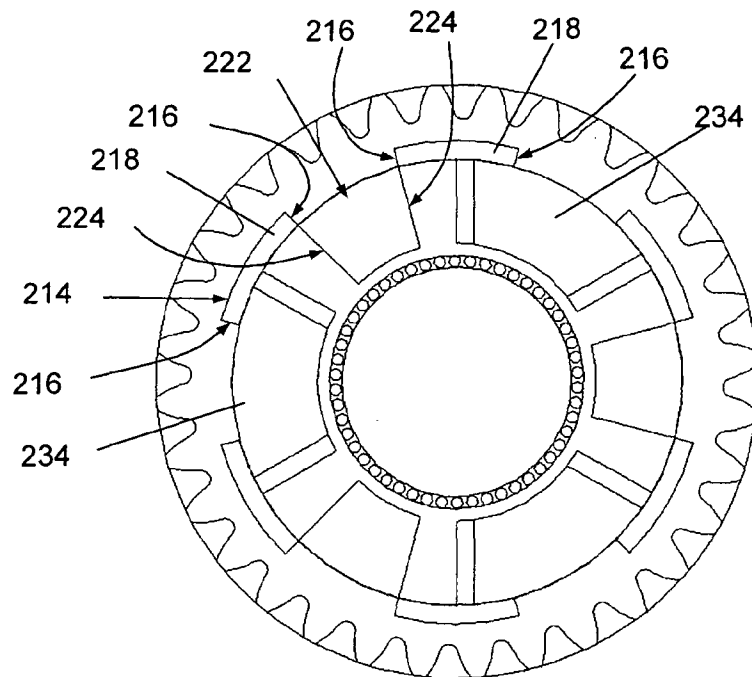


Fig. 2g

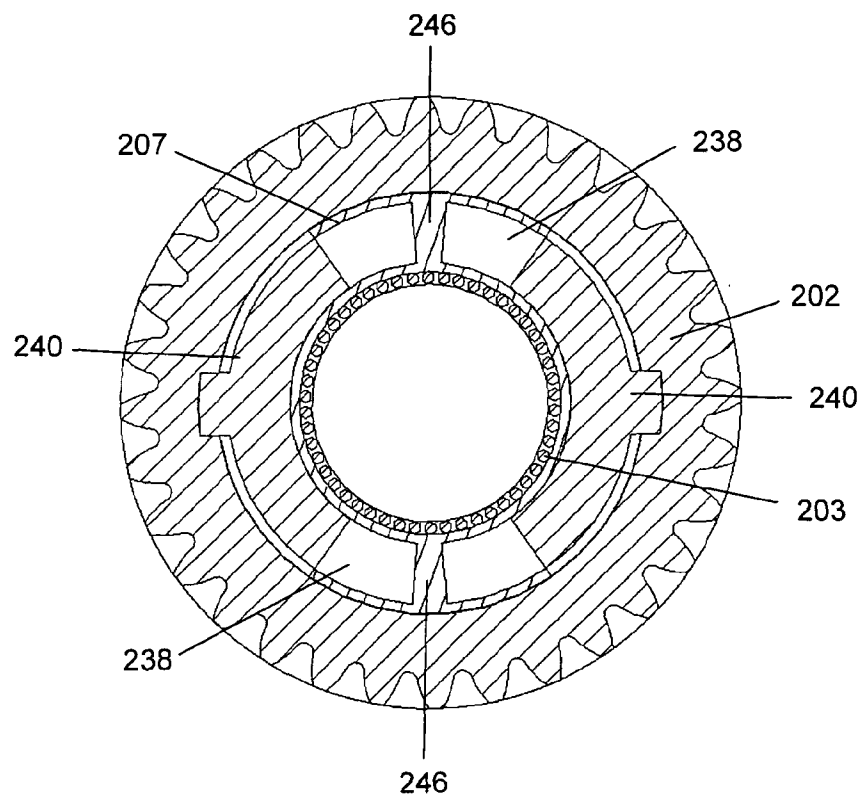


Fig. 2h

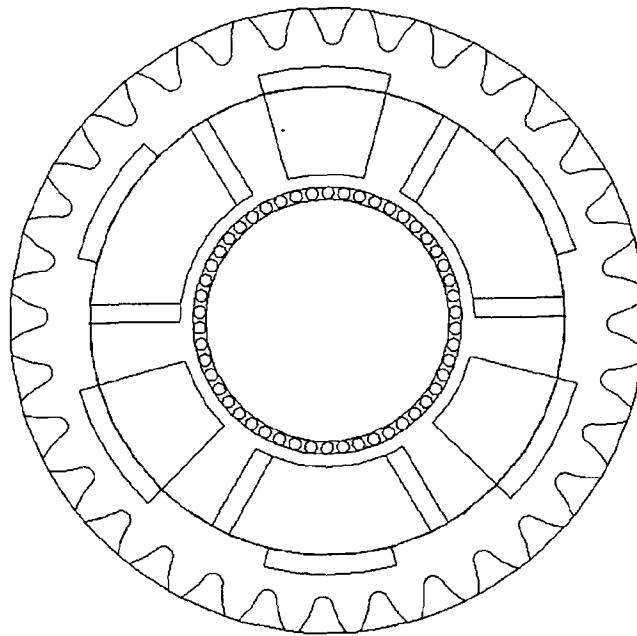


Fig. 2i

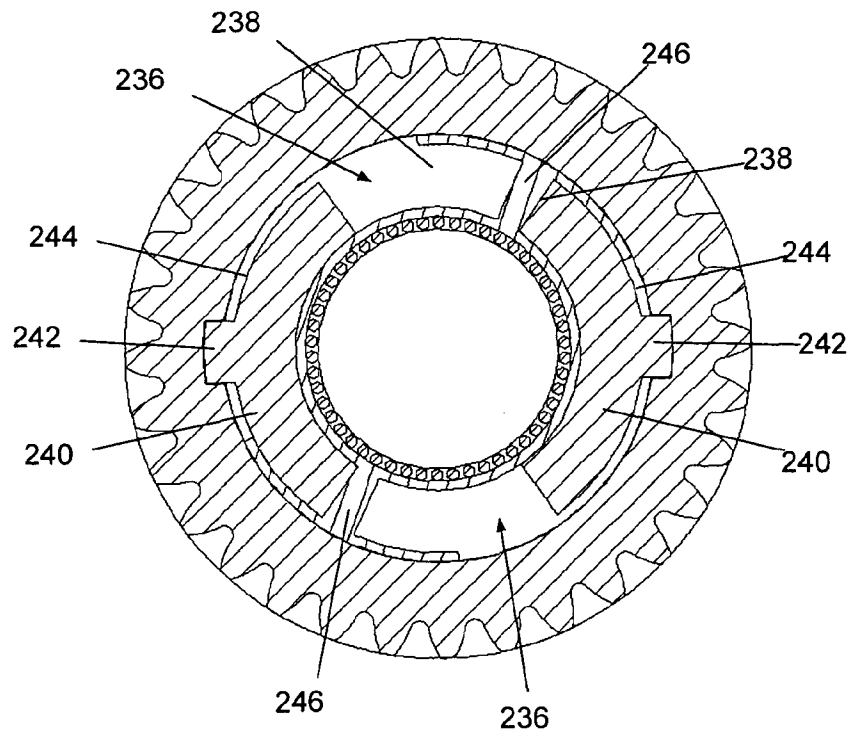


Fig. 2j

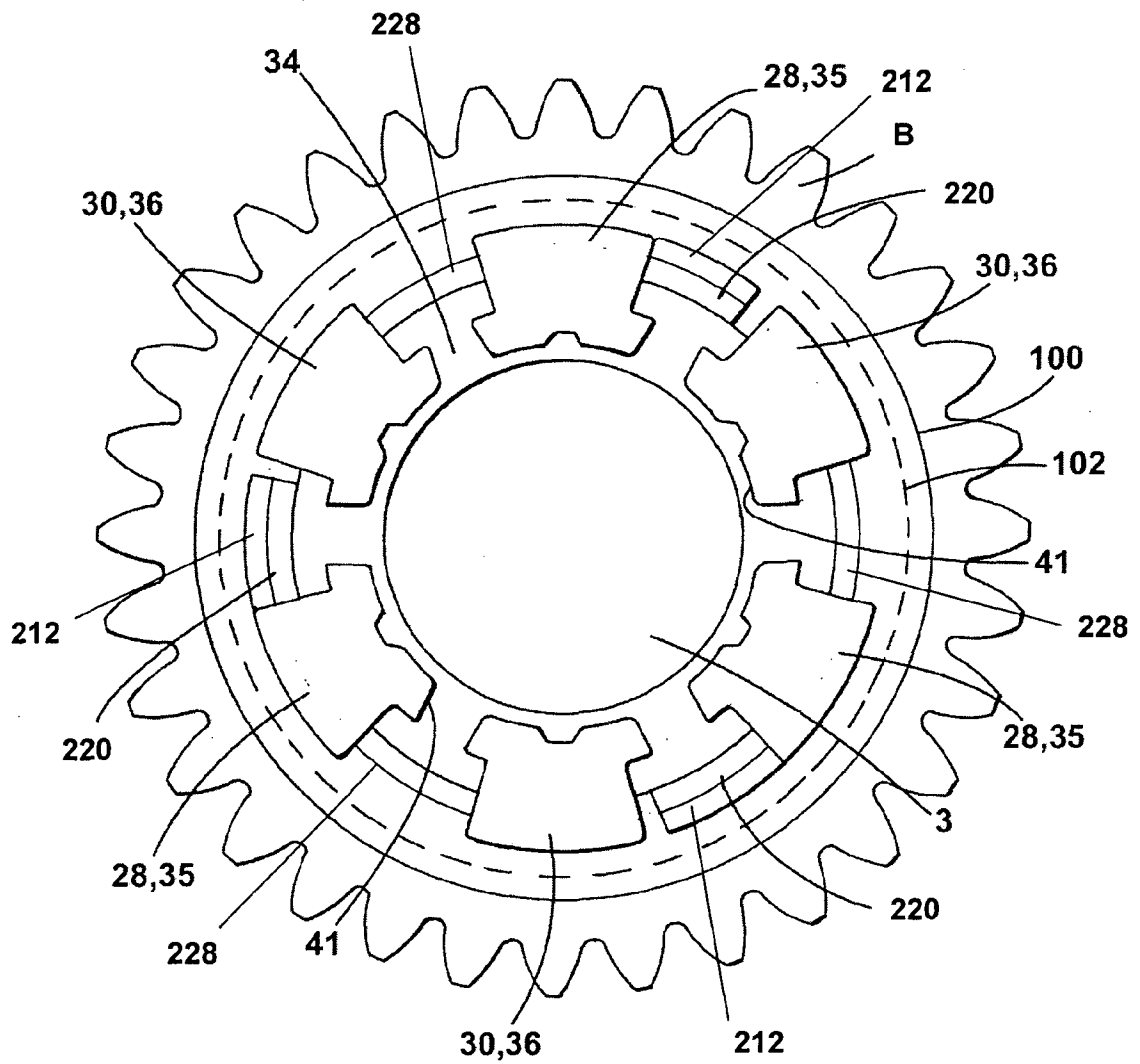


Fig. 3

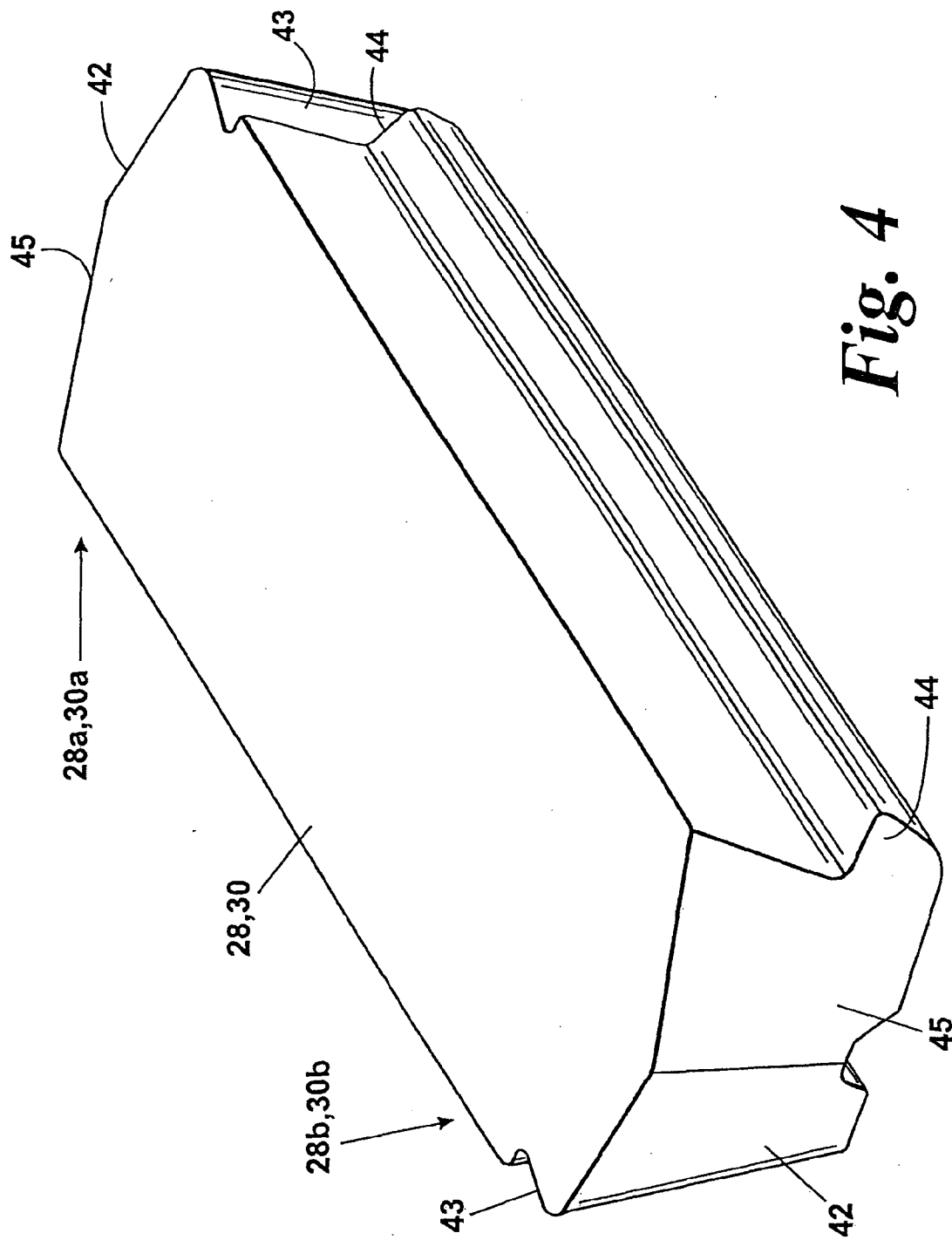
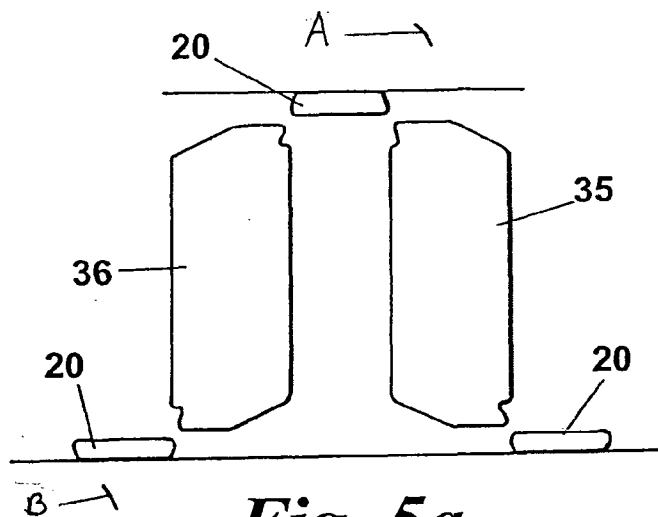
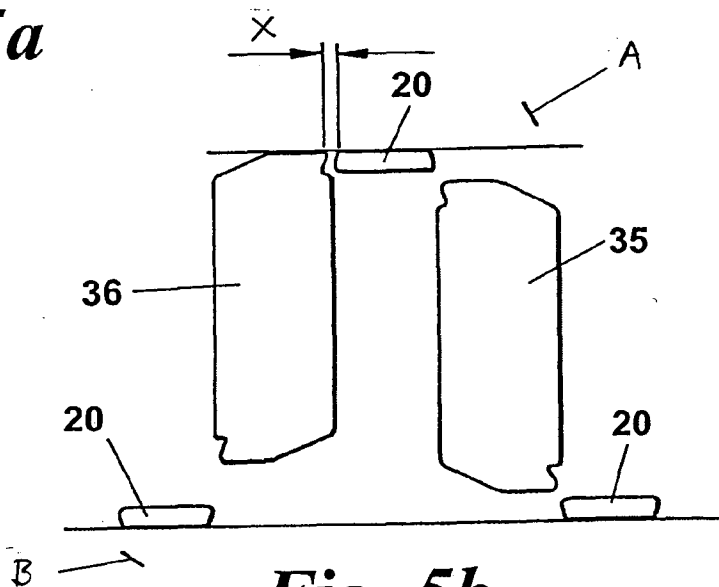
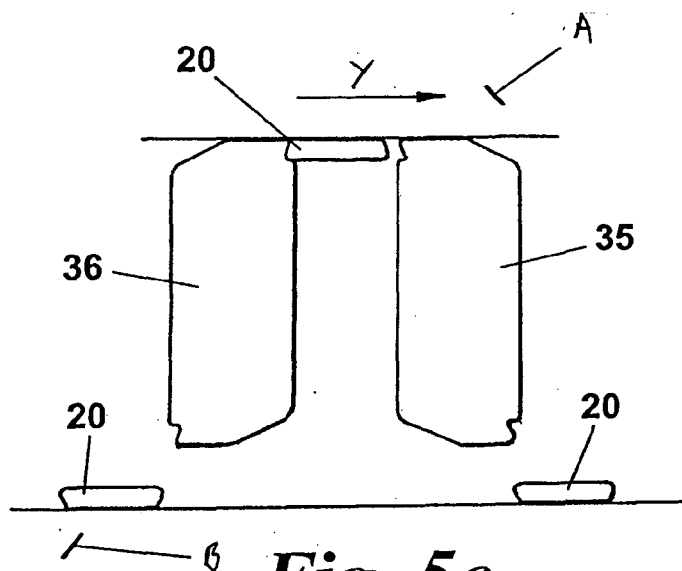


Fig. 4

**Fig. 5a****Fig. 5b****Fig. 5c**

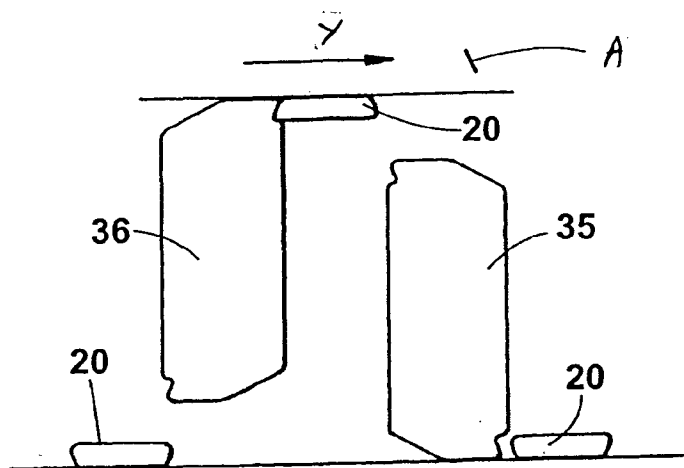


Fig. 5d

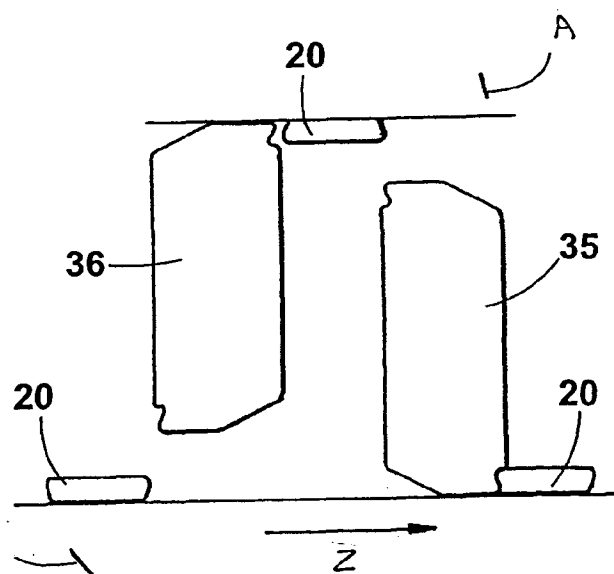


Fig. 5e

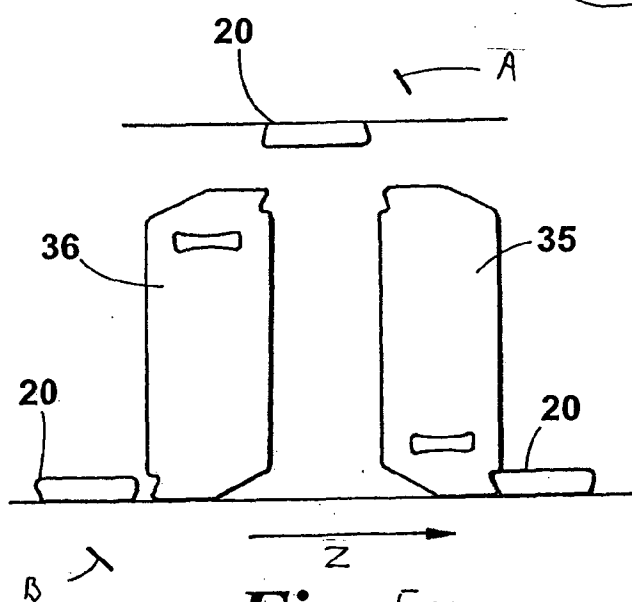
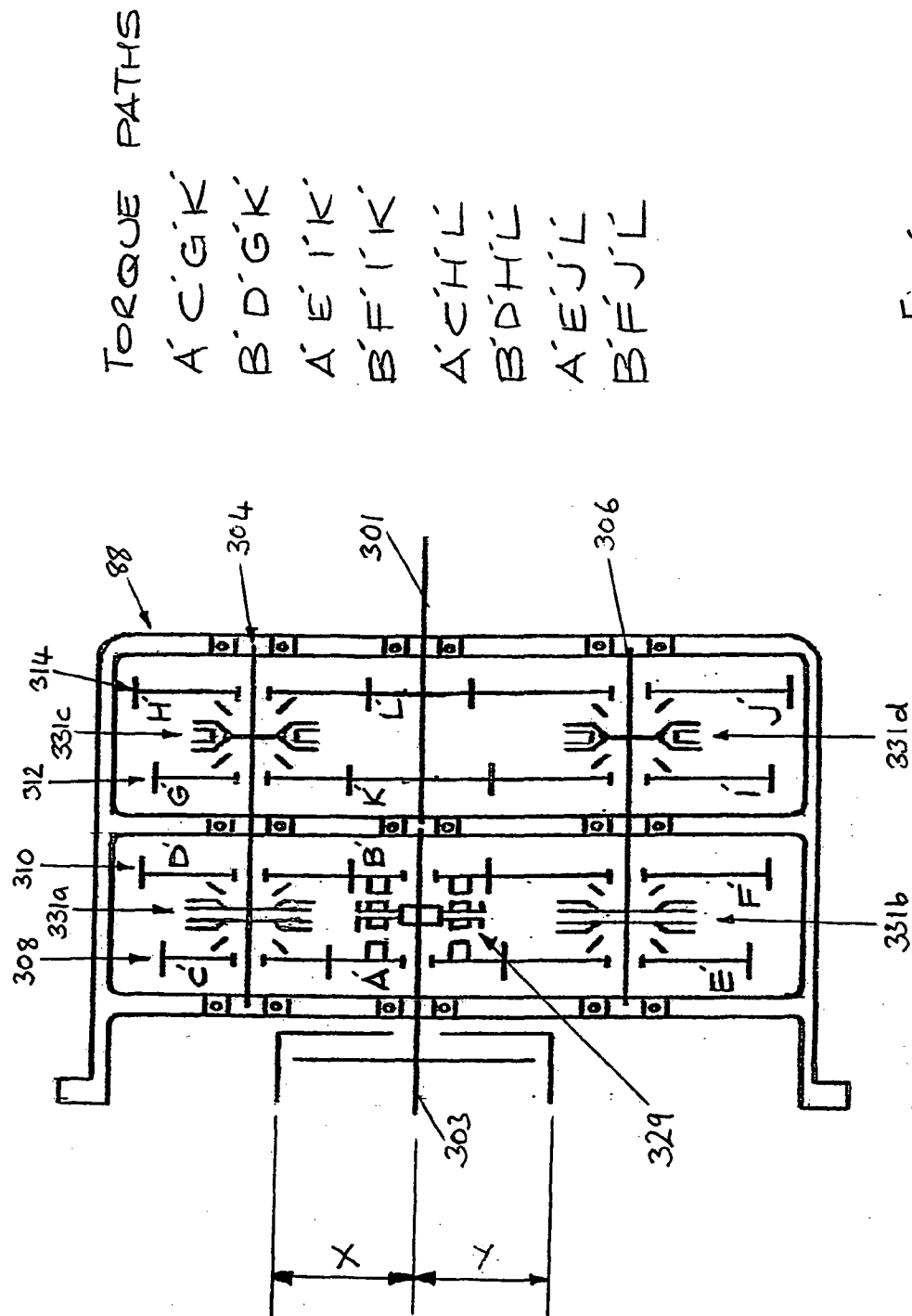


Fig. 5f



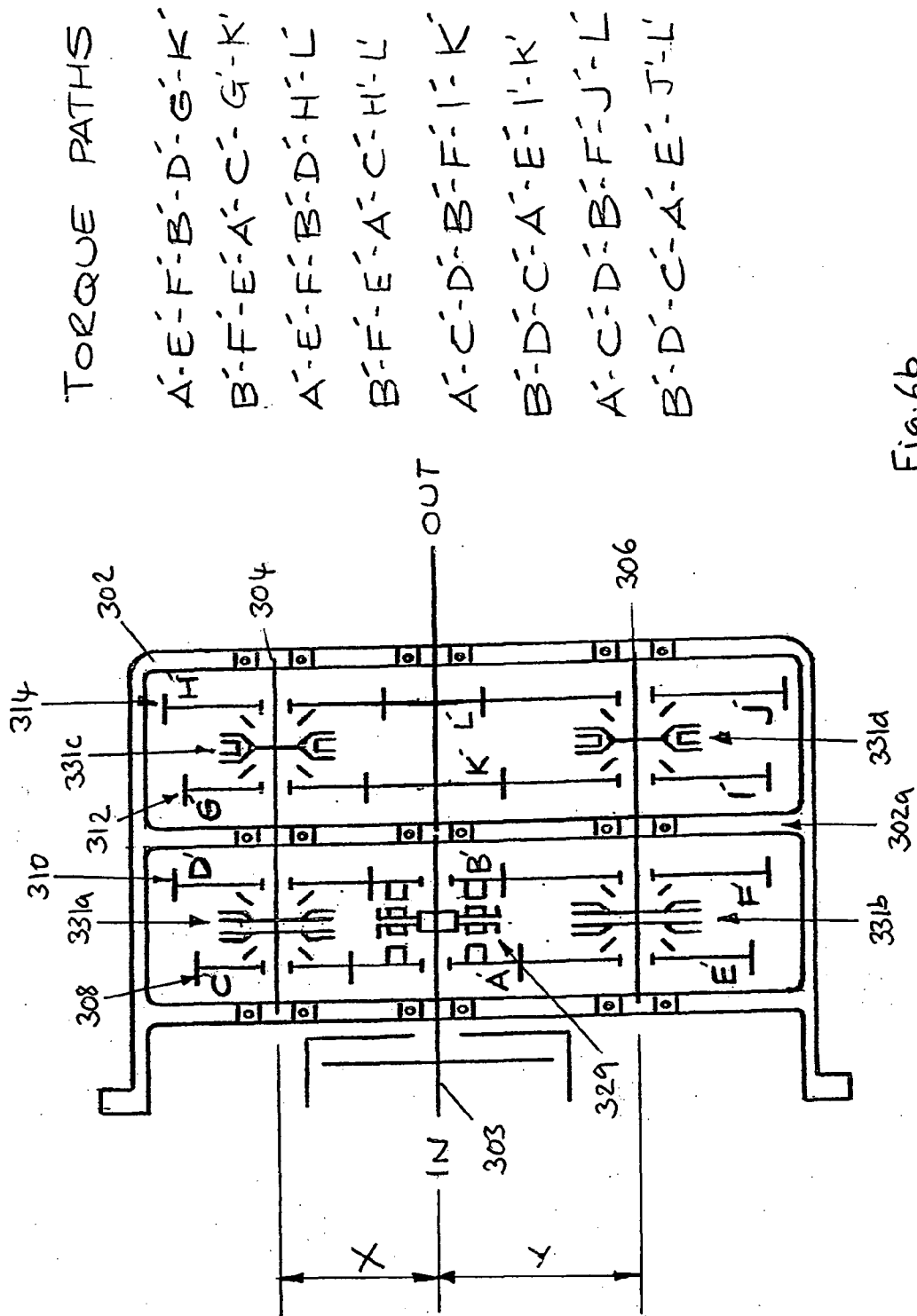
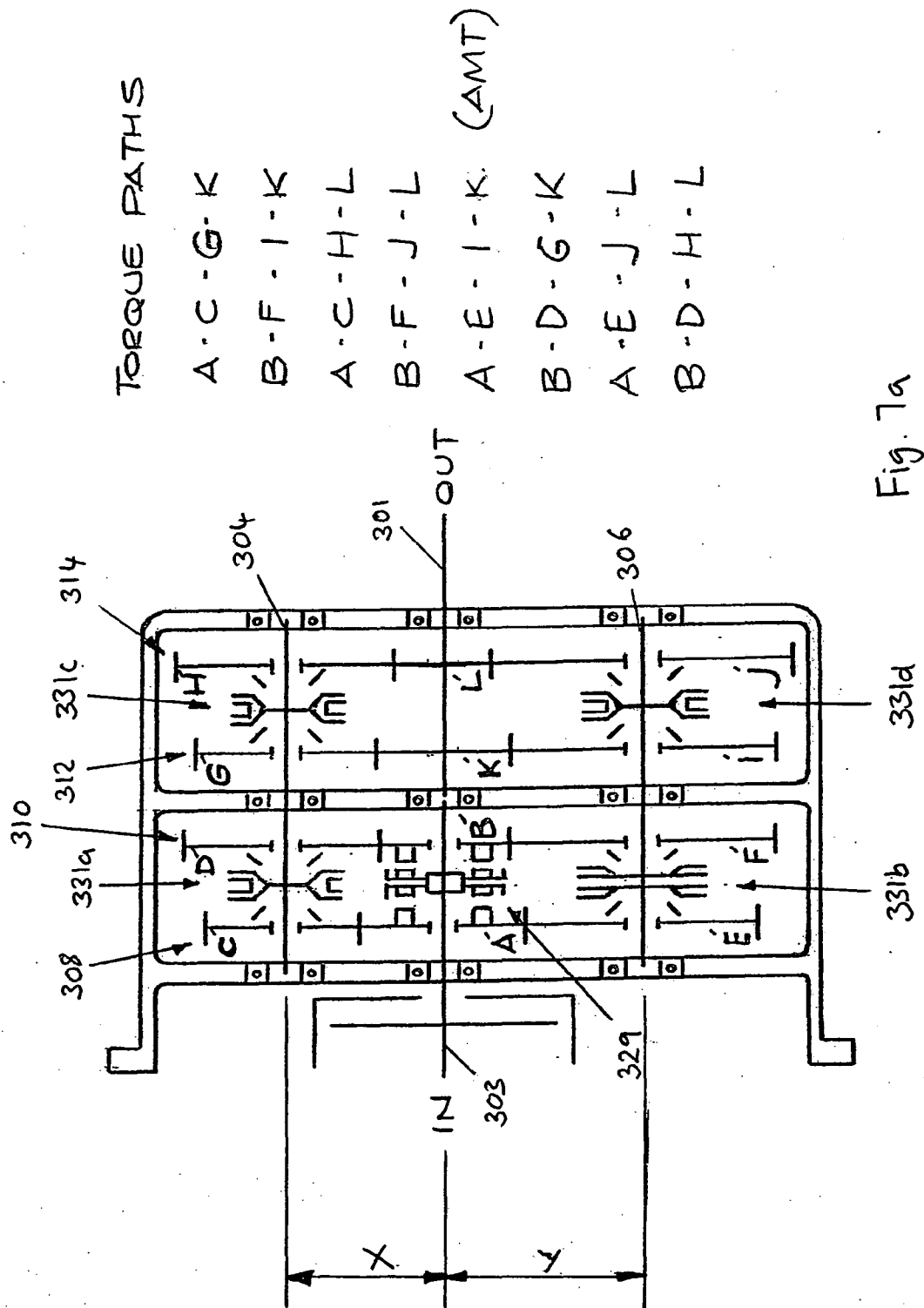


Fig. 6b



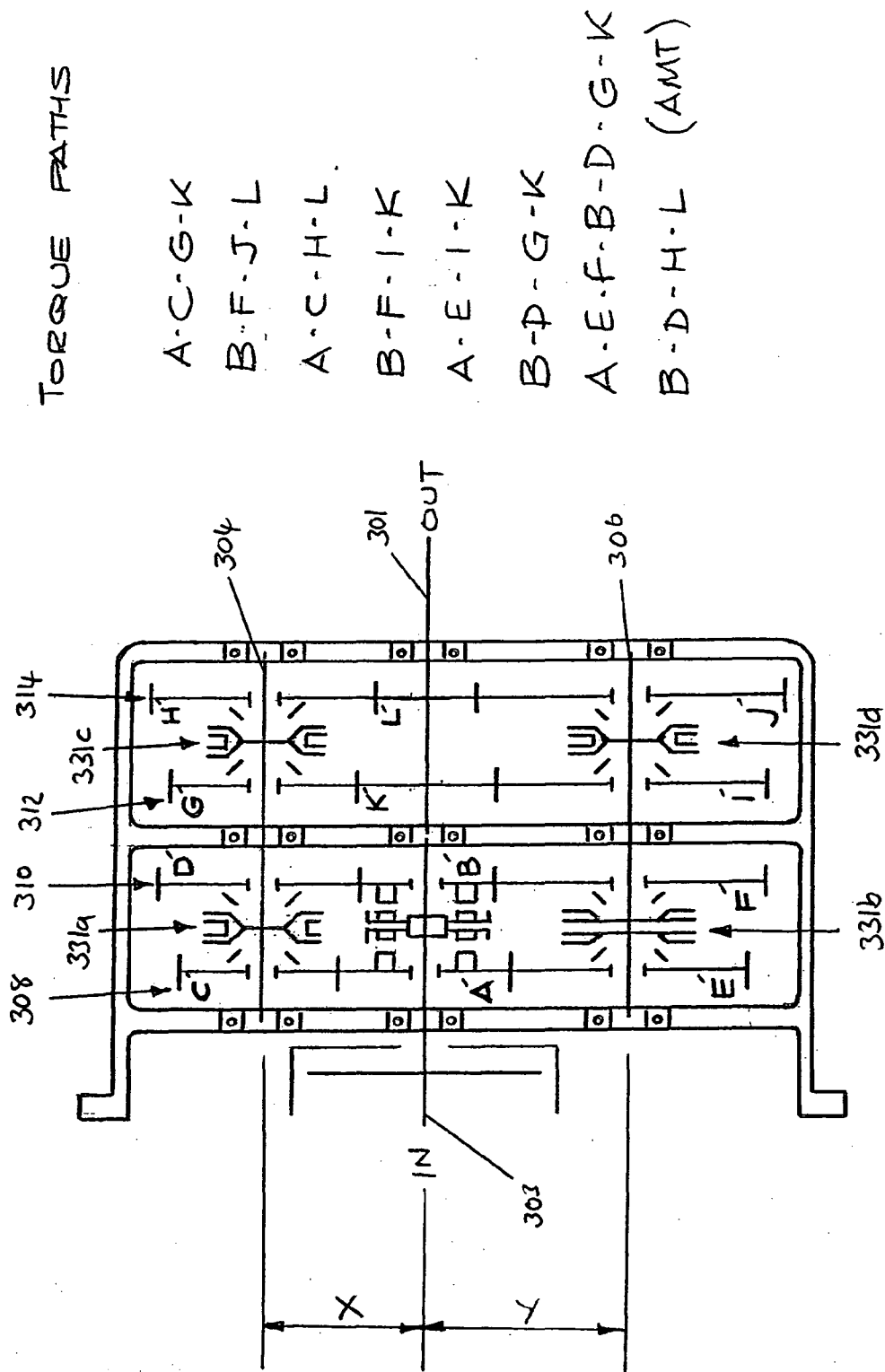


Fig. 7b

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2009/002528

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16H3/093

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)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 2008/062192 A1 (ZEROSHIFT LTD [GB]; MARTIN WILLIAM WESLEY [GB]; CHILD ANTHONY JOSEPH []) 29 May 2008 (2008-05-29) page 33, last paragraph - page 34, paragraph fourth; figures 15a-15b, 17a-17b page 1 - page 3, paragraph third	1-51
A	DE 26 44 113 A1 (BOCK JOHANN) 6 April 1978 (1978-04-06) figure 1	1-51
A	DE 199 24 501 A1 (DAIMLER CHRYSLER AG [DE]) 28 December 2000 (2000-12-28) figure 1	1-51

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

11 February 2010

Date of mailing of the international search report

24/02/2010

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Belz, Thomas

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/GB2009/002528

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
WO 2008062192	A1	29-05-2008	NONE	
DE 2644113	A1	06-04-1978	NONE	
DE 19924501	A1	28-12-2000	NONE	