A vehicle including a suspension system with a damper assembly acting transversely to dampen both heave and roll; and a damper assembly for such a vehicle

A vehicle comprises a sprung mass and left and right unsprung masses associated with left and right wheels 11 of a said left-right pair. A damper assembly 1 is mounted on the sprung mass and comprises a damper housing 3 defining a generally cylindrical chamber 4 having end walls 5, 6 at opposite axial ends thereof. Respective left and right damper rods 7, 8 are sealingly received through bores 9, 10 in these opposite axial end walls 5, 6 and are coupled respectively to the left and right unsprung masses. The respective left and right damper rods 7, 8 are arranged for movement into and out of the chamber 4 as their respective unsprung masses move relative to the sprung mass. The damper assembly provides damping both for heave and roll.

The damper assembly 1 may comprise a first cylinder defining respective left and right heave damper chambers 20, 21 separated by a bulkhead 19. Respective left and right damper rods 7, 8 of the assembly are respectively slidingly received through left and right axial end walls 17, 18 of the cylinder along a common axis. Each damper rod 7, 8 carries a respective damper piston 16 slidably within the respective left or right heave damper chambers 20, 21.

FIG. 2
VEHICLE

This disclosure relates to vehicles. More particularly it relates to vehicles with wheels arranged in left-right pairs, and is concerned with improvements in suspension systems therefor.

Suspension systems for vehicles are commonplace, and usually incorporate dampers to smooth the ride. In its travel, a vehicle may be subject to heave, roll and pitch; and suspension systems may accordingly employ a plurality of dampers, including hydraulic dampers, for damping one or more of heave, roll and pitch. The dampers often co-operate with helical, coach or torsion springs providing the primary suspension, the dampers serving to prevent excessive rebound in the spring suspension.

As will become clear from the detailed description below, particular embodiments disclosed herein have packaging advantages over conventional arrangements, and are particularly advantageous when embodied as an hydraulically integrated suspension system.

In accordance with a first aspect of this disclosure, a vehicle of the kind having wheels arranged in left-right pairs, comprises: a sprung mass; left and right unsprung masses associated with left and right wheels of a said left-right pair; and a damper assembly mounted on the sprung mass and comprising: a damper housing defining a generally cylindrical chamber therewithin having end walls at opposite axial ends thereof, respective left and right damper rods sealingly received through bores in said opposite axial end walls and coupled respectively to said left and right unsprung masses, the respective left and right damper rods being arranged for movement into and out of the chamber as their respective unsprung masses move relative to the sprung mass, and the damper assembly providing damping both for heave and roll.

The damper assembly preferably comprises a piston axially slidable in sealing engagement with the interior of the chamber, the left and right damper rods being coupled to said piston by a mechanism that causes the piston to be displaced from a datum within the chamber by a displacement which is an average of the displacements of the respective
damper rods from the same datum, whereby the position of the piston reflects the roll state of the suspension associated with the said left-right pair.

The said mechanism may comprise at least one screw carried by the piston for movement therewith as the piston is displaced in either axial direction from a datum, and for each of said at least one screw, left and right nuts respectively carried by the left and right damper rods, the or each said screw being rotatable but not displaceable relative to the piston, and, for a given screw, the left nut and a coacting portion of the screw being of one hand and the right nut and a coacting portion of the screw being of opposite hand.

The nuts should not rotate relative to each other. Accordingly, where there is only a single screw, the axis of which is aligned with the longitudinal direction of the damper rods, the damper rods on which the nuts are carried should be constrained for movement into and out of the chamber without rotation as their respective unsprung masses move relative to the sprung mass.

Where a plurality of parallel screws is employed or a single screw is eccentrically mounted relative to the longitudinal direction of the damper rods, no additional constraint is required.

Where there are several screws, the corresponding nuts carried by a particular damper rod need not all have the same handed thread.

Preferably the piston comprises a cylinder coaxially mounted within the chamber, and having left and right opposite axial end walls and a central bulkhead, thereby defining left and right internal chambers within said piston, the left and right damper rods respectively sealingly extending through bores in the left and right opposite axial end walls of the piston, and carrying respective left and right damper pistons axially slidable in sealing engagement with the interior of the respective left and right chambers, displacement of the left and right damper pistons from a datum within the said left and right chambers being indicative of heave.

Preferably a chamber defined between the left axial end of the damper housing chamber and the left axial end wall of the piston and serving as a left roll chamber, a
chamber defined between the left axial end wall of the piston and the left damper piston and serving as a left heave rebound chamber, a chamber defined between the left damper piston and the bulkhead and serving as a left heave bump chamber, and corresponding chambers on the right side of the damper assembly are each coupled via a respective restriction to a respective hydraulic reservoir.

In a four wheeled vehicle, chambers of a first said damper assembly associated with the front wheels and a second said damper assembly associated with the rear wheels may be hydraulically coupled. Coupled said chambers of the two said damper assemblies may be coupled via their respective restrictions to a common reservoir.

The damper assembly is believed novel *per se*.

Accordingly, there is provided, in a second and alternative aspect of this disclosure, a damper assembly comprising a first cylinder defining respective left and right heave damper chambers separated by a bulkhead; respective left and right damper rods respecitively slidingly received through left and right axial end walls of the cylinder along a common axis and each carrying a respective damper piston slidable within the respective left and right heave damper chambers; and a second cylinder coaxial with the first and within which the first cylinder is slidable as a piston, the left and right damper rods being slidingly received through axial end walls of the second cylinder, and the left and right damper rods being coupled to the first cylinder by a mechanism that causes the first cylinder to be displaced from a datum within the second cylinder by a displacement which is an average of the displacements of the respective damper rods from the same datum.

Reference is now made to the accompanying drawings, in which:

Fig. 1 is a somewhat schematic view of a front suspension system of a vehicle, the suspension system incorporating an hydraulic damper; and

Fig. 2 shows a schematic hydraulic circuit diagram linking respective damper assemblies associated with the front and rear wheels of a four wheeled vehicle.

Although the teachings of this disclosure may be applied to any vehicle of the kind having wheels arranged in left-right pairs, in practice the great majority of such vehicles will be four-wheeled. The description hereinbelow is written in terms of a four-wheeled
vehicle having front and rear suspension systems. Persons skilled in this art will readily appreciate from this description how the present teachings may be applied to vehicles with more than four wheels or with just one left-right pair, for example a three-wheeled vehicle.

Referring to Fig. 1, a damper assembly 1 is mounted to the vehicle sprung mass (not shown), usually in the form of a chassis, to straddle the centre-line 2 thereof. As explained in more detail below with reference to Fig. 2, damper assembly 1 comprises a damper housing 3 defining a generally cylindrical chamber 4 therewithin having end walls 5, 6 at opposite axial ends thereof. Respective left and right damper rods 7, 8 are sealingly received through bores 9, 10 in axial end walls 5, 6, and are coupled respectively to left and right unsprung masses, namely the wheels and associated parts of the vehicle. It will be appreciated that there will also be steering linkages and, in the case of a front-wheel drive or a four-wheel drive, a drive linkage, in each case not illustrated. For economy of illustration, only the right wheel 11 is shown. Linkages between the right unsprung mass and the sprung mass are illustrated only schematically in Fig. 1 for the purpose of explaining damping of the suspension system. In this example, right damper rod 8 is coupled via a connecting rod 12 to upper wishbone 13 of a double wishbone suspension system. Connecting rod 12 is coupled to damper rod 8 and to upper wishbone 13 by respective Hooke’s joints 14, 15. As the two front unsprung masses rise or fall relative to the sprung mass (heave), or one rises and the other falls (roll), the respective damper rods 7, 8 will move into and out of the chamber. The Hooke’s joints enable this movement without rotation of the damper rod.

Coaxially mounted within cylindrical chamber 4 is a generally cylindrical piston 16, which, as explained below, acts as a roll piston to damp rolling motion of the vehicle. Roll piston 16 has left and right opposite axial end walls 17, 18 and a central bulkhead 19 and defines left and right internal cylindrical chambers 20 and 21 within the piston, respectively between the left axial end wall 17 and the bulkhead 19 and between the right axial end wall 18 and the bulkhead 19. The left and right damper rods 7, 8 are respectively sealingly received through bores 22, 23 in left and right opposite axial end walls 17, 18. The damper rods 7, 8 carry respective left and right damper pistons 24, 25 which are axially slidable in sealing engagement with the interior of the respective left and right internal chambers 20, 21 of roll piston 16. The exterior of cylindrical wall 26 of roll piston 16 is spaced from the wall of cylindrical chamber 4, to define, together with sealing
rings 27, 28 and 29 carried, respectively, by the bulkhead 19 and left and right axial end walls 17 and 18 of roll piston 16 and further sealing rings 30 and 31 mounted on the wall of cylindrical chamber 4, annular spaces 32, 33, 34 and 35 respectively communicating with ports 36, 37, 38 and 39, and, via holes 40 in cylindrical wall 26, respectively with chambers 41, 42, 43 and 44 effectively defined within the left and right cylindrical chambers 20, 21 on either side of the left and right damper pistons 24, 25. Ports 36, 37, 38 and 39 also communicate via respective damping valves 45, 46, 47 and 48 providing selected restriction with respective hydraulic accumulators 49, 50, 51 and 52. The damping valves may be passive or may be adaptive, being electronically adjusted.

The illustrated damper assembly provides damping both for heave and roll. Heave is accommodated by movement of the left and right damper pistons 24, 25 within the left and right cylindrical chambers 20, 21 within the roll piston 16, coupled with the restriction of the damping valves and stiffness of the accumulators in the hydraulic circuits on the left and right side of the assembly.

In order that roll may also be damped, the left and right damper rods 7, 8 are also coupled to the roll piston 16 by a mechanism that causes the piston 16 to be displaced from a datum within the cylinder by a displacement which is an average of the displacements of the respective damper rods from the same datum to reflect the roll state of the left and right unsprung masses relative to the sprung mass. In the illustrated arrangement, this mechanism is provided by a screw 53 mounted in thrust and rotational bearings from the bulkhead 19. A housing 54 for these bearings is shown in the drawings, but the bearings themselves are omitted for economy of illustration. The thread of screw 53 is of opposite hands on opposite sides of bulkhead 19. Screw 19 threadedly cooperates with nuts 55, 56 respectively rotationally mounted to the ends of the damper rods 7, 8 in bearings at the centre of the damper pistons 24, 25. To accommodate the opposite ends of the screw 53, the damper rods 7, 8 must be hollow.

The screw need not be mounted on the axis of the assembly. There may also be more than one screw, in which case the damper pistons will carry the cooperating nuts. Where a plurality of parallel screws is employed or a single screw is eccentrically mounted, this feature will ensure that the damper pistons, and hence the nuts carried by them, are incapable of rotation relative to each other. Where there are several screws, the
corresponding nuts carried by a particular damper piston, and the cooperating portions of their respective screws need not all have the same handed thread, but for each screw the thread on opposite sides of the bulkhead must be of opposite hands. Eccentrically mounted screws may be supported for rotation but not displacement in one or more of the bulkhead 19 and left and right axial end walls 17, 18.

Rotation of one damper rod relative to the other may be restrained by other means. For example, the Hooke’s joint connections described above between the damper rods and respective connecting rods and between those connecting rods and upper wishbones of the suspension will achieve this, as would one or more prismatic rods mounted within the roll piston parallel to the axis of the cylinder, and along which the damper pistons sealingly slide.

It will be seen from the above description that the illustrated damper assembly provides, in an integrated fashion and within a single damper housing, respective chambers from left to right of the drawings that serve the following functions, namely:

- a chamber 57 defined between the left axial end wall 5 of the damper housing chamber and the left axial end wall 17 of the roll piston 16 and serving as a left roll chamber, being coupled hydraulically via a port 58 and a damping valve 59 providing selected restriction to an hydraulic accumulator 60,
- chamber 41 defined between the left axial end wall 17 of the roll piston 16 and the left damper piston 24 and serving as a left heave rebound chamber,
- chamber 42 defined between the left damper piston 24 and the bulkhead 19 and serving as a left heave bump chamber,
- and corresponding chambers 61, 44 and 43 on the right side of the damper assembly.

As shown in the hydraulic circuit diagram of Fig. 2, in one embodiment of four wheeled vehicle, chambers of a first said damper assembly 1 associated with the front wheels and of a second said damper assembly 101 associated with the rear wheels may be hydraulically coupled. For ease of identification, parts of damper assembly 101 are identified by reference numerals that are increased by 100 compared with the like parts of damper assembly 1.
Thus, the damper assemblies are interconnected by six hydraulic lines 62, 63, 64, 65, 66, 67 each being equipped with a respective accumulator 60, 49, 50, 51, 52 and 68 which each thus serve a chamber of damper assembly 1 and a chamber of damper assembly 101. The six lines create three hydraulic circuits as follows:

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<th>Rear Damper Chamber</th>
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<tr>
<td>Roll</td>
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<td>Left Roll Chamber 157</td>
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<tr>
<td></td>
<td>Right Roll Chamber 61</td>
<td>Right Roll Chamber 161</td>
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<tr>
<td>Heave</td>
<td>Right Heave Bump Chamber 43</td>
<td>Right Heave Bump Chamber 143</td>
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<tr>
<td></td>
<td>Right Heave Rebound Chamber 44</td>
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<tr>
<td>Pitch</td>
<td>Left Heave Bump Chamber 42</td>
<td>Left Heave Bump Chamber 142</td>
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<tr>
<td></td>
<td>Left Heave Rebound Chamber 41</td>
<td>Left Heave Bump Chamber 141</td>
</tr>
</tbody>
</table>

The vehicle may have no mechanical springs, being entirely dependent on the hydraulic circuits for its suspension. The stiffness of the respective accumulators, which are preferably gas backed, in each circuit will define the suspension stiffness for each suspension mode, and these are independently controllable. Assuming common bore, and rod diameters, and installed mechanical advantage front-to-rear, the warp stiffness of the vehicle will be zero with this arrangement. Warp, heave, roll and pitch stiffness balance front-to-rear may be altered by varying these parameters.

Fig. 2 shows a circuit for charging each line 62, 63, 64, 65, 66, 67 from an external reservoir 69 by means of a pump 70 and valves 71 and for discharging each line 62, 63, 64, 65, 66, 67 to external reservoir 69 via valves 72. For all three modes it is possible to adjust the static position by pumping fluid from one side of the circuit to the other. For example, it is possible to increase static ride height by pumping fluid from the right heave bump chambers 43, 143 to the right heave rebound chambers 44, 144. For all three modes it is also possible to adjust stiffness by pumping hydraulic fluid equally into both sides of the circuit to compress the gas in the accumulators and therefore increase the spring rate of the accumulators.

Numerous variations can be made in the hydraulic circuit to achieve different effects.
In one such arrangement, front and rear damper assemblies are not interconnected, or a damper assembly as described above is employed only for one wheel pair. Mechanical springs are provided, so that the damper is provided for damping only, namely to damp the velocity of spring displacement and not to provide the spring force itself. Accumulators are provided only to prevent cavitation and to account for volume changes due to damper rod area. In this arrangement, the roll chambers 57 and 61 are connected via a damping valve and each heave bump chamber is connected to its related heave rebound chamber via a damping valve. Alternatively, the two bump chambers on the one hand and the two rebound chambers on the other may be commonly connected via a single damping valve.

In another arrangement in which front and rear damper assemblies are also not interconnected, or a damper assembly as described above is employed only for one wheel pair, accumulators are provided for control of stiffness and static position of roll and heave modes. In this arrangement, each roll chamber is connected to an accumulator; heave bump chambers are connected together and connected to an accumulator; and heave rebound chambers are connected together and to an accumulator. Damping valves are provided at damper housing ports and/or accumulator ports.

In another possible arrangement, front and rear damper assemblies are interconnected front to rear in roll but not in heave. In this arrangement, the roll chambers are interconnected as shown in Fig. 2, while, for each damper assembly separately, the heave bump chambers are connected together and connected to an accumulator, and the heave rebound chambers are connected together and to an accumulator, as described above. Damping valves are provided at damper housing ports and/or accumulator ports.

In any of the arrangements described, mechanical springs can be provided in addition to the hydraulic scheme. This avoids the vehicle settling, as may occur in a purely hydraulic system.

Persons skilled in this art will appreciate that the drawings provided in this Application are schematic only and for the purpose of illustration, since the damper assembly in the drawings would be incapable of being manufactured. Both the damper housing 3 and the roll piston 16 must necessarily be formed as several separate parts to be
connected together in order that the components of the damper assembly may be assembled together. The particular way in which the damper housing and roll piston break down for assembly is immaterial to the teachings of this Application, and a mere matter of routine engineering choice for the manufacturer.

Numerous variations may be made from the arrangement illustrated.

Thus, wherever a sliding seal is provided, arrangements are feasible where the seal is provided on one or other of the two components that sealingly slide relative to each other.

Damper rods 7, 8 may respectively be connected directly to a suspension rocker or wishbone. In this case, damper assembly 1 would articulate with suspension movement. In this arrangement, the damper housing 3 would need to be restrained from lateral movement relative to the vehicle unsprung masses by a linkage or a gimbal mechanism.

Each damper rod 7, 8 may be connected to the respective unsprung mass of the suspension by various means known per se, such as via a connecting rod to a rocker and a pushrod or a pullrod between the rocker and one of a lower wishbone, upright or upper wishbone.

We prefer to employ ball nuts for nuts 55, 56 and a ball screw for screw 53, but other types of back driveable screw device could be used in place of a ball screw. With a sufficiently large thread pitch (in effect a helical spline), a plain nut without rolling elements could be used. Similarly plain bearings could replace rolling element bearings for support of the ball screw 53 relative to the roll piston bulkhead 19.

For certain hydraulic interconnection schemes the damper chambers can be internally connected for simplicity. Thus, the left and right heave bump chambers 42, 43 may be connected through holes in the roll piston bulkhead. Similarly, in place of external damping valves, conventional piston mounted damping valves may be employed. For example, the left and right damper pistons 24, 25 could have damping valves; and with this arrangement there is no need for external hydraulic connection to the heave chambers.
A flywheel may be added to the ball screw to add heave inertance to the suspension system.

The Hooke’s joints 14, 15 used to prevent relative rotation of the damper rods 7, 8 could be replaced with other types of non-rotation joints. With certain geometries parallel fulcrums could be used with compliant or non-compliant bushes.
Claims

1. A vehicle of the kind having wheels arranged in left-right pairs, comprises: a sprung mass; left and right unsprung masses associated with left and right wheels of a said left-right pair; and a damper assembly mounted on the sprung mass and comprising: a damper housing defining a generally cylindrical chamber therewithin having end walls at opposite axial ends thereof, respective left and right damper rods sealingly received through bores in said opposite axial end walls and coupled respectively to said left and right unsprung masses, the respective left and right damper rods being arranged for movement into and out of the chamber as their respective unsprung masses move relative to the sprung mass, and the damper assembly providing damping both for heave and roll.

2. A vehicle according to Claim 1, wherein the damper assembly comprises a piston axially slidable in sealing engagement with the interior of the chamber, the left and right damper rods being coupled to said piston by a mechanism that causes the piston to be displaced from a datum within the chamber by a displacement which is an average of the displacements of the respective damper rods from the same datum, whereby the position of the piston reflects the roll state of the suspension associated with the said left-right pair.

3. A vehicle according to Claim 2, wherein the said mechanism comprises at least one screw carried by the piston for movement therewith as the piston is displaced in either axial direction from a datum, and for each of said at least one screw, left and right nuts respectively carried by the left and right damper rods, the or each said screw being rotatable but not displaceable relative to the piston, and, for a given screw, the left nut and a coacting portion of the screw being of one hand and the right nut and a coacting portion of the screw being of opposite hand.

4. A vehicle according to Claim 3, wherein the at least one screw is a ball screw, and the left and right nuts are ball nuts.

5. A vehicle according to Claims 3 or 4, wherein there is only a single screw, the axis of which is aligned with the longitudinal direction of the damper rods, the damper rods on which the nuts are carried being constrained for movement into and out of the chamber without rotation as their respective unsprung masses move relative to the sprung mass.
6. A vehicle according to Claim 5, wherein the screw carries a flywheel.

7. A vehicle according to Claims 3 or 4, wherein there are a plurality of parallel screws, and wherein the plurality of nuts carried by a said damper rod do not all have the same handed thread.

8. A vehicle according to any preceding Claim, wherein the piston comprises a cylinder coaxially mounted within the chamber, and having left and right opposite axial end walls and a central bulkhead, thereby defining left and right internal chambers within said piston, the left and right damper rods respectively sealingly extending through bores in the left and right opposite axial end walls of the piston, and carrying respective left and right damper pistons axially slidable in sealing engagement with the interior of the respective left and right chambers, displacement of the left and right damper pistons from a datum within the said left and right chambers being indicative of heave.

9. A vehicle according to Claim 8, wherein a chamber defined between the left axial end of the damper housing chamber and the left axial end wall of the piston and serving as a left roll chamber, a chamber defined between the left axial end wall of the piston and the left damper piston and serving as a left heave rebound chamber, a chamber defined between the left damper piston and the bulkhead and serving as a left heave bump chamber, and corresponding chambers on the right side of the damper assembly, are each coupled via a restriction to an hydraulic reservoir.

10. A four wheeled vehicle according to Claim 9, provided with two said damper assemblies, a first said damper assembly being associated with the front wheels and a second said damper assembly being associated with the rear wheels, wherein at least some chambers of said first damper assembly and at least some chambers of said second damper assembly are hydraulically coupled, each coupled pair of chambers of the two said damper assemblies being coupled via a respective restriction to a common reservoir for the said pair by an hydraulic line.
11. A four wheeled vehicle according to Claim 10, wherein left roll chambers of the two said damper assemblies are coupled together and right roll chambers of the two damper assemblies are coupled together to damp roll of the vehicle as a whole.

5 12. A four wheeled vehicle according to Claim 10, wherein one of the left and right bump chambers of one said damper assembly is coupled to the same handed bump chamber of the other said damper assembly, and one of the left and right rebound chambers of one said damper assembly is coupled to the same handed rebound chamber of the other said damper assembly, whereby to damp heave of the vehicle as a whole.

10 13. A four wheeled vehicle according to Claim 10, wherein, for each said damper assembly, one of the left and right bump chambers thereof is coupled to one of the left and right rebound chambers of the other of the said damper assemblies, whereby to damp pitch of the vehicle as a whole.

15 14. A four wheeled vehicle according to Claim 10, wherein the vehicle has a suspension with no mechanical springs, being entirely dependent for its suspension upon hydraulic circuits comprising the two said hydraulically coupled damper assemblies, said hydraulic lines and said reservoirs.

20 15. A four wheeled vehicle according to Claim 10, wherein each of said reservoirs is gas backed, the vehicle further comprising a master pump and master reservoir selectively couplable via valves to individual said lines for adjusting the static position and/or the spring rate of individual said gas-backed reservoirs.

25 16. A vehicle according to Claim 8, wherein the suspension incorporates mechanical springs, the damper assembly being employed to damp the velocity of displacement of said springs; a chamber defined between the left axial end of the damper housing chamber and the left axial end wall of the piston and serving as a left roll chamber and a chamber defined between the right axial end of the damper housing chamber and the right axial end wall of the piston and serving as a right roll chamber are hydraulically interconnected via a restriction; a chamber defined between the left axial end wall of the piston and the left damper piston and serving as a left heave rebound chamber and a chamber defined between the left damper piston and the bulkhead and serving as a left heave bump
chamber are hydraulically interconnected via a restriction; and a chamber defined between the right axial end wall of the piston and the right damper piston and serving as a right heave rebound chamber and a chamber defined between the right damper piston and the bulkhead and serving as a right heave bump chamber are hydraulically interconnected via a restriction.

17. A vehicle according to Claim 8, wherein the suspension incorporates mechanical springs, the damper assembly being employed to damp the velocity of displacement of said springs; a chamber defined between the left axial end of the damper housing chamber and the left axial end wall of the piston and serving as a left roll chamber and a chamber defined between the right axial end of the damper housing chamber and the right axial end wall of the piston and serving as a right roll chamber are hydraulically interconnected via a restriction; a chamber defined between the left axial end wall of the piston and the left damper piston and serving as a left heave rebound chamber and a chamber defined between the right axial end wall of the piston and the right damper piston and serving as a right heave rebound chamber are commonly hydraulically connected via a restriction to a chamber defined between the left damper piston and the bulkhead and serving as a left heave bump chamber and to a chamber defined between the right damper piston and the bulkhead and serving as a right heave bump chamber.

18. A vehicle according to Claim 8, wherein a chamber defined between the left axial end of the damper housing chamber and the left axial end wall of the piston and serving as a left roll chamber is coupled to an accumulator via an hydraulic line and a restriction; a chamber defined between the right axial end of the damper housing chamber and the right axial end wall of the piston and serving as a right roll chamber is coupled to an accumulator via an hydraulic line and a restriction; a chamber defined between the left axial end wall of the piston and the left damper piston and serving as a left heave rebound chamber and a chamber defined between the right axial end wall of the piston and the right damper piston and serving as a right heave rebound chamber are coupled to a common accumulator via an hydraulic line and a restriction, optionally a common restriction; and a chamber defined between the left damper piston and the bulkhead and serving as a left heave bump chamber and to a chamber defined between the right damper piston and the bulkhead and serving as a right heave bump chamber are coupled to a common accumulator via an hydraulic line and a restriction, optionally a common restriction.
19. A four wheeled vehicle according to Claim 11, wherein, for each said damper assembly: the left heave rebound chamber and the right heave rebound chamber are coupled to a common heave rebound accumulator for that damper assembly via an hydraulic line and a restriction, optionally a common restriction; and the left heave bump chamber and the right heave bump chamber are coupled to a common heave bump accumulator for that damper assembly via an hydraulic line and a restriction, optionally a common restriction.

20. A vehicle substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

21. A damper assembly comprising a first cylinder defining respective left and right heave damper chambers separated by a bulkhead; respective left and right damper rods respectively slidingly received through left and right axial end walls of the cylinder along a common axis and each carrying a respective damper piston slidable within the respective left and right heave damper chambers; and a second cylinder coaxial with the first and within which the first cylinder is slidable as a piston, the left and right damper rods being slidingly received through axial end walls of the second cylinder, and the left and right damper rods being coupled to the first cylinder by a mechanism that causes the first cylinder to be displaced from a datum within the second cylinder by a displacement which is an average of the displacements of the respective damper rods from the same datum.

22. A damper assembly substantially as hereinbefore described with reference to and as shown in the accompanying drawings.
**Application No:** GB0810774.0  
**Examiner:** Miss Natalie Coombs  
**Claims searched:** 1-20  
**Date of search:** 8 July 2008

**Patents Act 1977: Search Report under Section 17**

**Documents considered to be relevant:**

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**Categories:**

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
& Member of the same patent family  
A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
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**Field of Search:**

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X^:
Worldwide search of patent documents classified in the following areas of the IPC

B60G

The following online and other databases have been used in the preparation of this search report

EPODOC, WPI

International Classification:

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