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(56) Documents Cited
GB 2270049 A **GB 2144378 A** **GB 1379865 A**
GB 0363811 A **WO 91/04877 A1** **WO 84/02887 A1**

(58) Field of Search
UK CL (Edition N) **B7D DCD**
INT CL^6 **B60G 21/06 21/067 21/073**

(54) Hydraulic suspension

(57) A hydraulic suspension system for a vehicle, the system comprising independent idler cylinders 5, 6 for receiving inputs from hydraulic actuators 1, 2 linked to two respective road wheels and for summing movements of the wheels representing bump movement into a bump spring 19 and for summing differential movements of the wheels representing roll motion into a roll spring 15a, 15b.

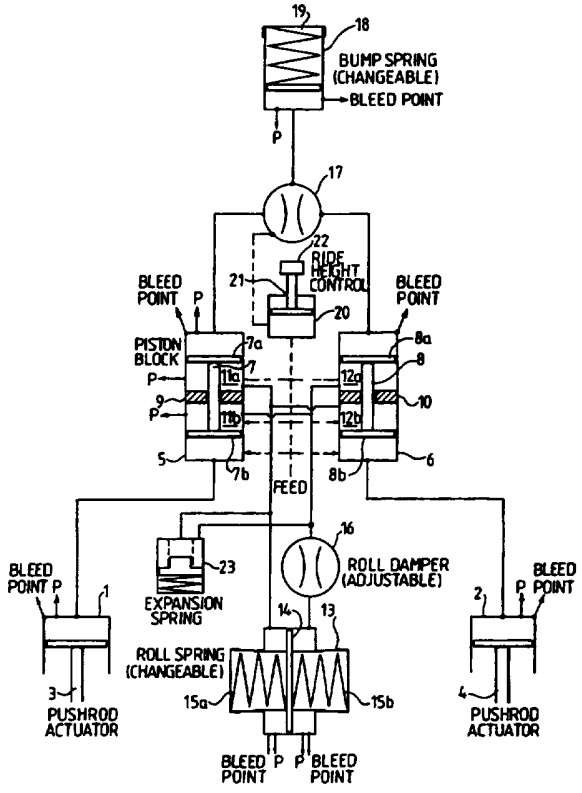

Fig.1.

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

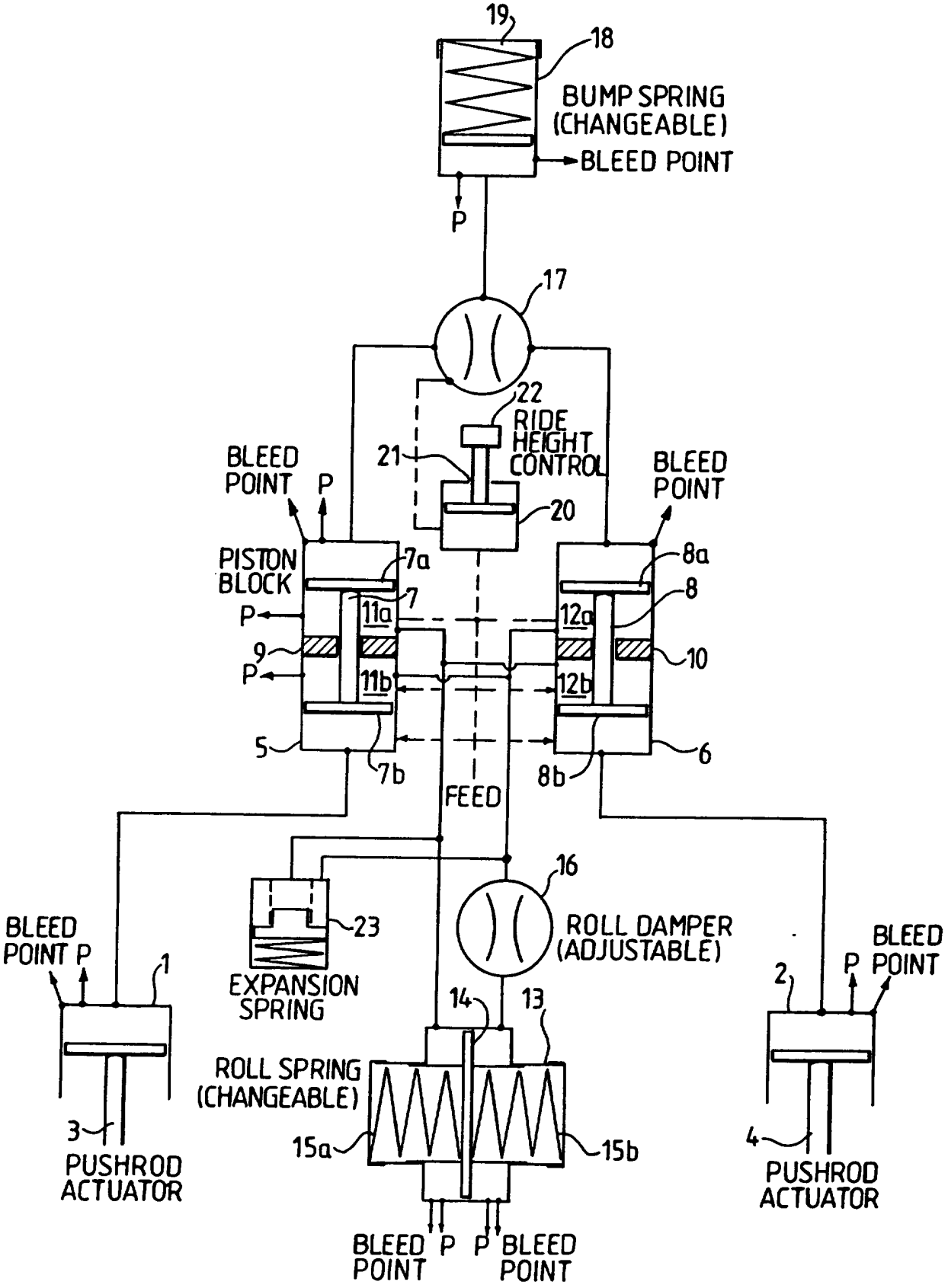
19
18
BUMP SPRING
(CHANGEABLE)
BLEED POINT
P
17
22
RIDE
HEIGHT
CONTROL
21
20
BLEED
POINT
P
BLEED
POINT
PISTON
BLOCK
7a
8a
7
8
11a
12a
P
9
10
P
11b
12b
5
7b
8b
6
FEED
16
ROLL DAMPER
(ADJUSTABLE)
23
EXPANSION
SPRING
BLEED
POINT P
1
2
P
BLEED
POINT
14
13
ROLL SPRING
(CHANGEABLE)
15a
15b
3
4
PUSHROD
ACTUATOR
PUSHROD
ACTUATOR
BLEED
POINT
P
P
BLEED
POINT

Fig.1.

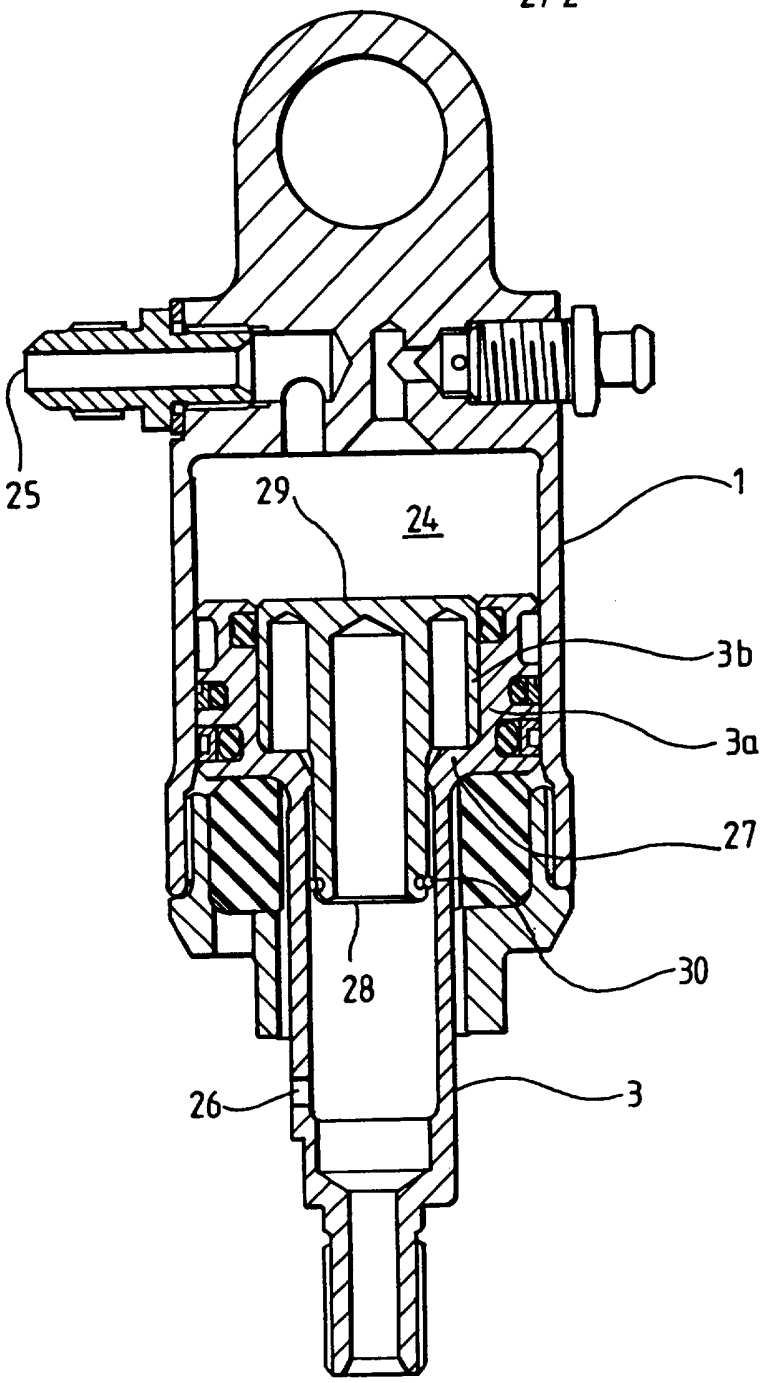

Fig.2.

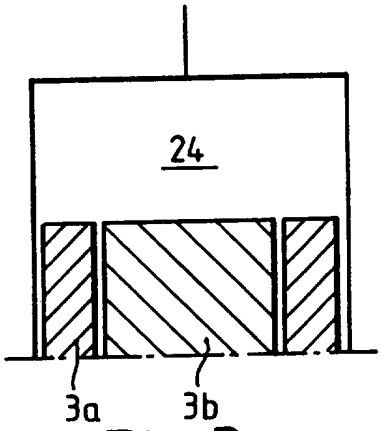

Fig.3a.

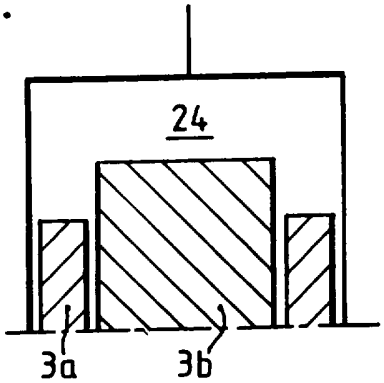

Fig.3b.

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HYDRAULIC SUSPENSION

This invention relates to a hydraulic suspension system. In particular, it relates to a passive hydraulic suspension system for a vehicle. The vehicle may be a car, for example a racing car.

Vehicle suspension systems are designed to cope with many different types of conditions and movements of the vehicle with respect to a road surface. Of particular importance are up and down movements of the vehicle, hereinafter known as bump, when both front or rear wheels go up and down generally together and roll movements, which generally occur during cornering or when only one wheel encounters an undulation or obstruction in the road surface. Vehicle suspension designers have in the past generally had to design separate systems for compensating for bump and roll, which can lead to complexity and extra weight or have had to have single systems which compensate for both these effects but which involve a trade-off of one against the other. Thus, prior art suspension systems which have been optimised for anti-roll properties had generally not been optimised also for bump or heave movements, and vice versa.

More recently, active suspension systems involving microprocessor controlled electronics have evolved. However, these can be electronically complex and in some environments, such as under certain motor racing regulations, they are disallowed.

Existing suspension systems also take up a considerable amount of space and add weight to a vehicle, both of which are properties which it is desired to reduce as much as possible in racing or sports vehicles. The physical positioning of the various components of the suspension system of existing vehicles can adversely affect a vehicles balance and weight distribution and it would be desirable to be able to use a suspension system,

the main components of which can be placed in a position in a vehicle which optimises the vehicles weight distribution and balance.

The present invention arose in an attempt to provide an improved hydraulic suspension system for a road vehicle which can optimise performance for both bump and roll movements of the vehicle.

It is also an object of the present invention to provide a suspension system, the main components of which can be placed as desired on the vehicle so as to optimise the vehicles weight distribution.

According to the present invention there is provided a hydraulic suspension system for a vehicle, the system comprising means for receiving inputs from hydraulic actuators linked to two respective road wheels and for summing movements of the wheels representing bump movement into a bump spring and for summing differential movements of the wheels representing roll motion into a roll spring.

Preferably the system comprises two hydraulic cylinders, each receiving an input from a respective road wheel and having an output directly proportional to its input to transmit bump movement to a summing element for summing into the bump spring.

The cylinders may have a first internal chamber arranged to be compressed when a wheel rises and to expand when the wheel lowers and a second chamber, not connected to the first chamber, for expanding when the wheel rises and compressing when the wheel lowers, the first chamber of one cylinder being hydraulically connected to the second chamber of the second cylinder and to one side of the roll spring and the second chamber of the first cylinder being connected to the first chamber of the second cylinder and the other side of the roll spring such that differential movements of the two wheels, causing a

roll effect, act on one or other side of the roll spring.

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

Figure 1 shows schematically a hydraulic suspension system;

Figure 2 shows a pushrod actuator; and

Figures 3A and 3B are explanatory diagrams.

Referring to Figure 1, a hydraulic suspension system comprises a pair of respective hydraulic cylinders 1, 2 each connected via a respective pushrod actuator 3, 4 to a respective road wheel (not shown). These will typically be the front or rear wheels of a road vehicle and a separate system may be used for each pair of wheels. Cylinders 1 and 2 are linked by hydraulic lines to a respective pair of independent idler cylinders 5, 6. Each of these includes an I-shaped piston 7, 8 displaceable longitudinally within the cylinder. An aperture barrier 9 divides the area between the enlarged end portions 7a and 7b of piston 7 into two separate chambers 11a and 11b. Similarly, two separate chambers 12a and 12b are formed by a barrier 10 in the right hand cylinder 6. The stems of the pistons 7 and 8 are free to move longitudinally through the aperture in dividers 9 and 10 but seals (not shown) are provided so that fluid is substantially prevented from flowing from chamber 11a to 11b for example.

As shown in the figure, chamber 11a is hydraulically connected to chamber 12b and chamber 11b is hydraulically connected to chamber 12a. Connected chambers 11a and 12b are also connected to the left side of a roll spring chamber 13. Similarly, chambers 11b and 12a are also connected to the right hand side of roll chamber 13. Roll chamber 13 includes a plate 14 held within the hydraulic fluid by two opposing roll springs

15a, 15b. The value of these may be variable or selectable to adjust the roll characteristics of the vehicle. Normally, when the vehicle is not rolling, these springs exert an equal pressure and plate 14 is central within the chamber. An adjustable roll damper 16 is included in one of the paths from the connected chamber to roll cylinder 13. Hydraulic dampers are well known and the damper may comprise a hydraulic cylinder having an apertured plate bearing a plurality of small apertures which present a resistance to hydraulic fluid passing therethrough and therefore have a damping effect.

The uppermost chambers of the two idler cylinders 5 and 6 are both hydraulically connected to a bump damper 17, again of conventional damper design. The output of the damper is connected to a bump cylinder 18 having a bump spring 19 which is variable or selectable to alter the vehicles bump characteristics. Spring 19 is affected by the amount of hydraulic fluid entering the cylinder at its input point.

The system may also include a ride height control means 20 which is essentially a hydraulic cylinder having a piston 21 which can be raised or lowered manually by control 22. This may be a simple screw mechanism. Lowering piston 21 causes hydraulic fluid in the cylinder 20 to enter damper 17 which therefore acts back through idler cylinders 5 and 6, pushing respective pistons 7 and 8 downwards in the figure through to the pushrod actuators 1 and 2 to depress the pushrods 3 and 4 and thus raise the body of the vehicle with respect to its wheels. The ride height control may be positioned at any suitable point in the circuit and need not be restricted to the position shown in the figure.

Thermal expansion compensating means may be provided to compensate for thermal expansion of the hydraulic fluid if necessary. This may be by a simple

expansion spring cylinder 23.

Various hydraulic feed and bleed positions are also shown in the figure to allow for replenishment and/or bleeding of the hydraulic fluid. In order to monitor the system, displacement transducers (as are known in the art) may be used to monitor the displacements of various pistons such as 3, 4 or springs 15a, 15b and 18.

The functioning of the hydraulic system will now be described.

In practice, the vehicle's motion will usually involve a combination of bump and roll movements. During bump movements, ie when the wheels attached to pushrods 3 and 4 both move up, hydraulic fluid is applied into the lower most chambers of idler cylinders 5 and 6. This pushes both pistons 7 and 8 upwards causing hydraulic fluid flow cylinders 5 and 6 to flow into damper 17 and thus to be summed into bump cylinder 18. The total bump effect is therefore compensated for in a desired manner by the bump spring 19, which may of course be variable or selectable in order to adjust the settings.

Note that terms such and up and down, lower and upper when referring the hydraulic cylinder only refer to the disposition shown in figure. In practice, the apparatus could lie in any disposition.

During a roll movement, the relative effect is that one of the wheels moves upwards whilst the other wheel moves relatively downwards. If the right wheel moves upwards for example, push rod 4 will move up in the figure, causing hydraulic fluid to be pushed into idler cylinder 6 whilst the associated relative downward movement of the left wheel causes pushrod 3 to move down, thus drawing hydraulic fluid from idler cylinder 5 into cylinder 1. Hence, idler piston 8 in cylinder 6 moves upwards whilst idler piston 7 in cylinder 5 moves downwards. Upwards motion of the piston 8 causes chamber

12b to compress and chamber 12a, on the other side of barrier 10, to expand. Similarly, downwards movement of piston 7 causes chamber 11b to expand and chamber 11a to compress. Since chambers 11a and 12b are connected and both of these are compressed during this particular roll movement, hydraulic fluid is caused to flow into the left hand side of roll chamber 13. This causes an excess pressure to be applied on the left hand side of plate 14 and causes hydraulic fluid to be sent from the right hand chamber of the roll cylinder into the now expanded chambers 11b and 12a of the respective idler cylinders. It will be appreciated that a roll damper may be situated anywhere in the fluid path between the first connected pair of chambers 11a and 12b and the second connected pair 11b and 12a. Springs 15a and 15b are of course changeable or variable in order to adjust the roll characteristics of vehicle.

Thus, during roll, the hydraulic system detects a different between the movements of the wheels, as opposed to the summing of the movements during bump movement. These summing and difference movements are completely independent so that the system compensates independently yet simultaneously for both bump and roll whether these effects are manifested independently or together. Usually, of course, motion will involve a degree of both bump and roll.

One problem that can arise with hydraulic suspension systems is that of negative pressure when a wheel temporarily leaves the road surface. It will be seen from Figure 1 that if the wheel connected to pushrod 3 were to leave the road surface the weight of the wheel, unsupported by any reaction from the ground, tends to pull on pushrod 3. This may create a negative pressure within cylinder 1 which may tend to draw air into the cylinder or to otherwise effect the hydraulic system adversely.

Figure 2 shows in more detail the cylinder 1 showing a mechanism for compensating for any negative pressure. Some of the components in the figure are seals and other components which do not directly bear on the invention and are thus not explicitly described. Essentially, piston 3 slides within cylinder 1 and hydraulic fluid is held within chamber 24. An output from chamber 24 is shown at 25. In this example, piston 3 comprises an outer piston 3a and a radially inner piston 3b. These can slide longitudinally with respect to one another. The piston is vented direct to the atmosphere at vent 26. Outer piston 3a includes an inner shoulder 27 which, during upwards movement of the piston ensure that inner piston 3b is pushed along with outer piston 3a. If the hydraulic pressure within chamber 24 increases then, clearly, both the inner and outer pistons would move downwards together due to equal pressure upon them. However, if there is a negative pressure in chamber 24, caused by a wheel mechanically connected to piston 3 leaving the road for example, then since the interior of the piston is at atmospheric pressure due to vent 26, the inner piston 3b will be forced upwards by greater pressure at its lower end 28 and at its upper end 29 and thus will compensate for the negative pressure, restoring the pressure in chamber 24 back to atmospheric pressure. The piston 3b is sealed towards its edge 28 by seal 30 from outer piston 3a. Thus, piston 3a will remain generally stationary during negative pressure compensation.

The effect is shown schematically in Figure 3 which shows at Figure 3A the normal position of the inner and outer pistons 3a and 3b during normal hydraulic pressure and, at Figure 3B, the situation when a negative pressure is accounted in chamber 24 in which inner pistons 3b move longitudinally relative to outer piston 3a to restore pressure within the chamber by reducing its

volume. Many variations within this concept may be envisaged.

A significant advantage of the present invention is that the main components can all be integrated into a single unit. This may be formed from a metal casting for example and may include integral chambers forming idler cylinders 5 and 6, damper 18 and 17, the rod and bump chambers 13 and 18 and the ride height control 20 and expansion chamber 27 if necessary. The required pistons, springs, seals, etc can all then be fitted into the unit as necessary. Since the unit is hydraulically linked to a pair of wheels it can be placed virtually anywhere within the automobile, linked by flexible pipes.

CLAIMS

1. A hydraulic suspension system for a vehicle, the system comprising means for receiving inputs from hydraulic actuators linked to two respective road wheels and for summing movements of the wheels representing bump movement into a bump spring and for summing differential movements of the wheels representing roll motion into a roll spring.

2. A suspension system as claimed in Claim 1 comprising two hydraulic cylinders, each receiving an input from a respective road wheel and having an output directly proportional to its input to transmit bump movement to a summing element for summing into the bump spring.

3. A suspension system as claimed in Claim 2, wherein the cylinders each have a first internal chamber arranged to be compressed when a wheel rises and to expand when the wheel lowers and a second chamber, not connected to the first chamber, for expanding when the wheel rises and compressing when the wheel lowers, the first chamber of one cylinder being hydraulically connected to the second chamber of the second cylinder and to one side of the roll spring and the second chamber of the first cylinder being connected to the first chamber of the second cylinder and the other side of the roll spring such that differential movements of the two wheels, causing a roll effect, act on one or other side of the roll spring.

4. The suspension system as claimed in Claim 3, wherein each cylinder comprises an I-shaped piston, an input chamber and an output chamber and the two differential chambers are positioned longitudinally between the enlarged ends of the I piston and separated by a divider through which the stem of the piston is movable.

5. A suspension system as claimed in any one of the preceding claims, wherein dampers are provided in the roll

output and/or the bump output.

6. A hydraulic suspension system as claimed in any one of the preceding claims, wherein the hydraulic actuators linked to the road wheels comprise piston means linked to the road wheels and slidable longitudinally within a hydraulic cylinder, the piston means having two radially spaced pistons, one of which is vented to the atmosphere such that in the event of negative pressure within the hydraulic chamber, the vented piston slides relative to the other piston to compensate therefor.

7. A suspension system as claimed in any one of the preceding claims further comprising thermal expansion compensating means.

8. A suspension system as claimed in any one of the preceding claims further comprising a ride height control means comprising a piston mounted in a hydraulic cylinder the piston being manually adjustable within the cylinder to increase or decrease the amount of hydraulic fluid in the rest of the system and thereby raise or lower the vehicle with regard to the wheels.

9. A suspension system as claimed in any one of the preceding claims, comprising an integral assembly receiving the hydraulic inputs.

10. A hydraulic cylinder comprising piston means having two radially spaced pistons, one of which is vented to the atmosphere such that in the event of negative pressure within the hydraulic chamber, the vented piston slides relative to the other piston to compensate therefor.

11. A hydraulic cylinder as claimed in Claim 10, wherein the piston is the radially inner piston.

12. A hydraulic suspension system for a vehicle substantially as hereinbefore described with reference to, and as illustrated by, the accompanying drawings.

The Patent Office

Application No: GB 9504210.7
Claims searched: 1 to 9

Examiner: Colin Thompson
Date of search: 18 May 1995

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.N): B7D (DCD)

Int Cl (Ed.6): B60G 21/06, 21/067, 21/073

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2270049 A	(Rover Group Ltd)	1, 2
X	GB 2144378 A	(Alfa Romeo Auto SpA)	1, 2, 3
X	GB 1379865 A	(Nissan Motor Co Ltd)	1, 2
X	GB 0363811 A	(Adamson)	1, 2
X	WO91/04877A1	(Heyring)	1, 2
X	WO84/02887A1	(Nakata)	1, 2

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