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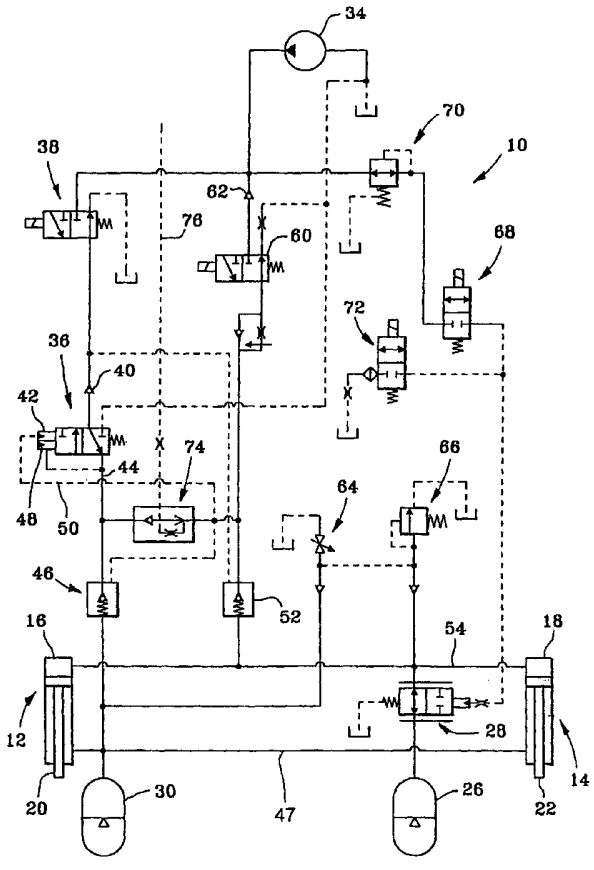
(54) Title: VEHICLE SUSPENSION CONTROL SYSTEM



(57) Abstract: A vehicle suspension system includes a fluid pump (34), a pair of suspension cylinders (12, 14) and a hydraulic control circuit for controlling pressurization of the suspension cylinders (12, 14). Each suspension cylinder (12, 14) has a head end and a rod end. The control circuit includes a proportional rod pressure control valve (36) with a first pilot (42) which is exposed to a pressure which is communicated to the head end of the suspension cylinder (12, 14), and a second pilot (48) which is exposed to pressure which is communicated to the rod end of the suspension cylinder (12, 14). The rod pressure control valve (36) controls pressure in the rod end of the suspension cylinder (12, 14) as a function of and proportional to the pressure in the head end of the suspension cylinder (12, 14). A suspension damping valve (28) controls communication between a chamber of the cylinder (12, 14) and an accumulator (26).

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VEHICLE SUSPENSION CONTROL SYSTEM

BACKGROUND OF INVENTION

[01] The present invention relates to a suspension system for a vehicle, such as a heavy duty tractor. the present invention further relates to a hydraulic control circuit for such a suspension system.

[02] Heavy duty tractors have been provided with front axle hydraulic suspension systems which include a pair of hydraulic cylinders connected between the frame and the axle of the tractor. One such system is described in DE-A-4242448. Such suspension systems also include hydraulic accumulators and can perform a chassis leveling function. Such tractors are subject to a wide range of axle loads, and these loads can exceed the normal pressure range of the accumulator. If an implement is attached to such a tractor, implement operation can produce large changes in load and chassis attitude which can interfere with implement control and with chassis attitude control. Leveling response time can be slow because flow to both the head and rod ends of the cylinders must be controlled by a pair of solenoid operated valves.

[03] Such systems use a fixed pressure regulator to control rod side pressure or uses a common head and rod pressure. To achieve the maximum load range it is desirable to have a high rod pressure when the head pressure is low and a low rod pressure when the head pressure is high. To maintain level tractor attitude and better implement control it is desirable to restrict vertical chassis displacement when significant changes are anticipated. It is not desirable to block flow on both sides due to the potential to work head and rod against each other due to flow into the cylinder or thermal effects.

[04] Such prior systems also do not allow for independent rod and head charging. As a result, flow typically goes to the rod side first, which is the path of

least resistance. This results in delayed leveling operation, and results in the discharge of rod side oil that was just introduced into the rod side, thus wasting energy.

SUMMARY

[05] Accordingly, an object of this invention is to provide a hydraulic suspension control system and to provide a hydraulic control circuit therefore which can accommodate a wide range of loads.

[06] A further object of the invention is to provide such a system and control circuit which avoids delayed leveling operation.

[07] A further object of the invention is to provide such a system and control circuit which does not waste energy by discharging rod side oil.

[08] A further object of the invention is to provide such a system and control circuit which maintains level tractor attitude and which has improves implement control.

[09] These and other objects are achieved by the present invention according one of the claims 1 and 9. Further advantageous arrangements and developments of the invention appear from the dependent claims.

[010] In an advantageous embodiment of the present invention a hydraulic control circuit is provided for a vehicle suspension system having a fluid pump and suspension cylinders, each having a head end and a rod end. The control circuit includes a proportional rod pressure control valve with a pair of pilots. The first pilot is exposed to a pressure which is communicated to the rod end of the suspension cylinder. The second pilot is exposed to pressure which is communicated to the head end of the suspension cylinder. The rod pressure control valve controls pressure in the rod end of the suspension cylinder as a

function of and proportional to the pressure in the head end of the suspension cylinder. System pressure is communicated to the rod pressure control valve via a solenoid operated raise/lower valve. In order to achieve the maximum load range, the system produces a high rod pressure when the head pressure is low and produces a low rod pressure when the head pressure is high.

[011] Vertical chassis displacement is restricted to maintain level tractor attitude and provide better implement control by blocking flow between the cylinders and accumulators on one side of the suspension. Pilot pressure is applied to the damping valve rapidly to respond quickly to load changes. Flow between cylinders and accumulators may be completely blocked. This results in a significant pressure differential between cylinders and accumulators. To control pressure equalization, pilot pressure is metered off across an orifice. The metering opens the damping valve slow enough so that the controller may respond to position changes by leveling, closing the pilot exhaust valve to hold the damping valve in position or reapplying pilot pressure to start the opening process again.

[012] As an alternative to completely blocking flow between cylinders and accumulators, it is desirable to orifice flow between cylinders and accumulators. Gradual pressure equalization can easily be made up by leveling flow. When pressure is partially or completely taken care of by the equalization orifice, control requirements are simplified and the transition from damped to undamped operation is quick and seamless. The equalization orifice also improves safety by insuring that the cylinders and accumulators can be drained by the same elements, and insures equalization if the tractor is shut off while the suspension is in damped condition, thus avoiding unexpected motion if the damping valve opens at a later time.

[013] The head and rod ends may be independently charged in order to achieve prompt leveling operation, and in order to avoid the discharge of rod side oil, thus saving energy. Flow can be applied to the head side first to accomplish a portion of the leveling before flow/pressure is applied to the rod side to set the rod side

pressure. For this purpose, the head and rod side of the system are cross piloted.

BRIEF DESCRIPTION OF THE DRAWINGS

[014] The invention and further advantageous developments and arrangements of the invention will now be described and explained in more detail by way of example and with reference to the accompanying drawings.

[015] The sole Figure is a hydraulic circuit diagram of a vehicle hydraulic suspension system according to the present invention.

DETAILED DESCRIPTION

[016] The Figure shows a vehicle suspension system 10, such as for a front axle (not shown) of a tractor (not shown), which includes a pair of suspension cylinders 12, 14, each having a housing 16, 18 coupled to a frame (not shown) of the vehicle and a rod 20, 22 coupled to a front axle part (not shown), such as a front axle lower arm (not shown). The head chambers of cylinders 12, 14 are connected to accumulator 26 via a pilot operated suspension damping valve 28. The rod chambers of cylinders 12, 14 are connected to accumulator 30.

[017] System pressure from pump 34 is supplied to proportional rod pressure control valve 36 via solenoid operated raise/lower valve 38 and rod side anti-craning check valve 40. Valve 36 includes a first pilot 42 which is exposed to the pressure which is communicated to the head chambers of the cylinders 12 and 14 via line 50, head side pilot operated check valve 52, and line 54. Valve 36 includes a second pilot 48 which is exposed to the pressure which is communicated to the rod chambers of the cylinders 12 and 14 via line 44, rod side pilot operated check valve 46 and line 47. As a result, the pressure in the rod chambers of cylinders 12, 14 is controlled as a function of and is proportional to the pressure in the head chambers of cylinders 12, 14.

[018] System 10 includes a solenoid operated raise valve 60 which can be activated to communicate system pressure from pump 34 via check valve 62 to the head chambers of cylinders 12, 14 via check valve 52 and line 54. A manually operated drain valve 64 can be operated to communicate the rod and head chambers of cylinders 12, 14 to sump. Pressure relief valve 66 relieves or limits pressure in the rod and head chambers of cylinders 12, 14 by communicating the same to sump if the pressure in the chamber of cylinders 12, 14 exceeds a certain level.

[019] A solenoid operated lock valve 68 controls communication of pressure from pump 34 and pressure reducing valve 70 to the pilot of pilot operated suspension damping valve 28. Thus, when valve 68 is activated the pilot of valve 28 is pressurized and valve 28 blocks communication between the head chambers of cylinders 12, 14 and accumulator 26, thus holding constant the amount of fluid in the head chambers of cylinders 12, 14. This restricts vertical chassis displacement and helps to maintain level tractor attitude and provide better control of an implement (not shown) which may be attached to the tractor (not shown).

[020] A solenoid operated unlock valve 72 controls communication of pressure between sump and the pilot of pilot operated suspension damping valve 28. Thus, when valve 72 is activated the pilot of suspension damping valve 28 is de-pressurized and valve 28 opens communication between the head chambers of cylinders 12, 14 and accumulator 26, thus allowing the amount of fluid in the head chambers of cylinders 12, 14 to vary.

[021] The lock function is rapid in order to respond to changes in implement loads. Unlocking is controlled so that pressure differences between head and rod chambers can be adjusted. The system 10 meters flow between the cylinders and the accumulators during a portion of the stroke of the damping valve 28, and then opens fully for minimum restriction of flow between the cylinders and accumulators during unlocked operation. The system 10 is also bi-stable so no change of state occurs in the event of electric or hydraulic power loss.

[022] A shuttle check valve 74 with load sense bleed communicates pressure from the outlet of rod pressure control valve 36 to a load sense line 76, and the supply side of the head side of the pilot operated check valve 52.

[023] While the present invention has been described in conjunction with a specific embodiment, it is understood that many alternatives, modifications and variations will be apparent to those skilled in the art in light of the foregoing description. Accordingly, this invention is intended to embrace all such alternatives, modifications and variations which fall within the spirit and scope of the appended claims.

Claims

1. A hydraulic control circuit for a vehicle suspension system having a fluid pump (34) and at least one suspension cylinder (12, 14) having a head chamber and a rod chamber, the control circuit comprising:

a proportional rod pressure control valve (36) having a first pilot (42) which is exposed to a pressure which is communicated to the head chamber of the suspension cylinder (12, 14), and a second pilot (48) which is exposed to pressure which is communicated to the rod chamber of the suspension cylinder (12, 14), the rod pressure control valve (36) controlling pressure in the rod chamber of the suspension cylinder (12, 14) as a function of and proportional to the pressure in the head chamber of the suspension cylinder (12, 14).

2. The control circuit of claim 1, further comprising:

a solenoid operated raise/lower valve (38) which controls communication of system pressure to the rod pressure control valve (36).

3. The control circuit of claim 2, wherein:

the raise/lower valve (38) is solenoid operated.

4. The control circuit of one of the claims 1 to 3, further comprising:

a solenoid operated raise valve (60) which can be activated to communicate system pressure from pump (34) via check valve (62) to the head chamber via a check valve (52).

5. The control circuit of one of the claims 1 to 4, further comprising:

a manually operated drain valve (64) which can be operated to communicate the rod and/or head chambers to sump.

6. The control circuit of one of the claims 1 to 5, further comprising:

a pressure relief valve (66) which limits pressure in the rod and/or head chambers by communicating the rod and/or head chambers to sump if the pressure in the chamber exceeds a certain level.

7. The control circuit of one of the claims 1 to 6, further comprising:

an accumulator (26); and

a suspension damping valve (28) for controlling communication between a chamber of the cylinder (12, 14) and accumulator (26).

8. The control circuit of one of the claims 1 to 7, further comprising:

an accumulator (26);

a pilot operated suspension damping valve (28) for controlling communication between a chamber of the cylinder (12, 14) and accumulator (26); and

a lock valve (68) for controlling communication between the pump (34) and a pilot of the suspension damping valve (28).

9. A vehicle suspension system coupled between a frame and axle of the vehicle, comprising:

a fluid pump (34);

at least one suspension cylinder (12, 14) having a first chamber coupled to the frame and a second chamber coupled to the axle; and

a control circuit for controlling fluid communication between the pump (34) and the cylinder (12, 14) which, the control circuit is arranged according one of the preceding claims.

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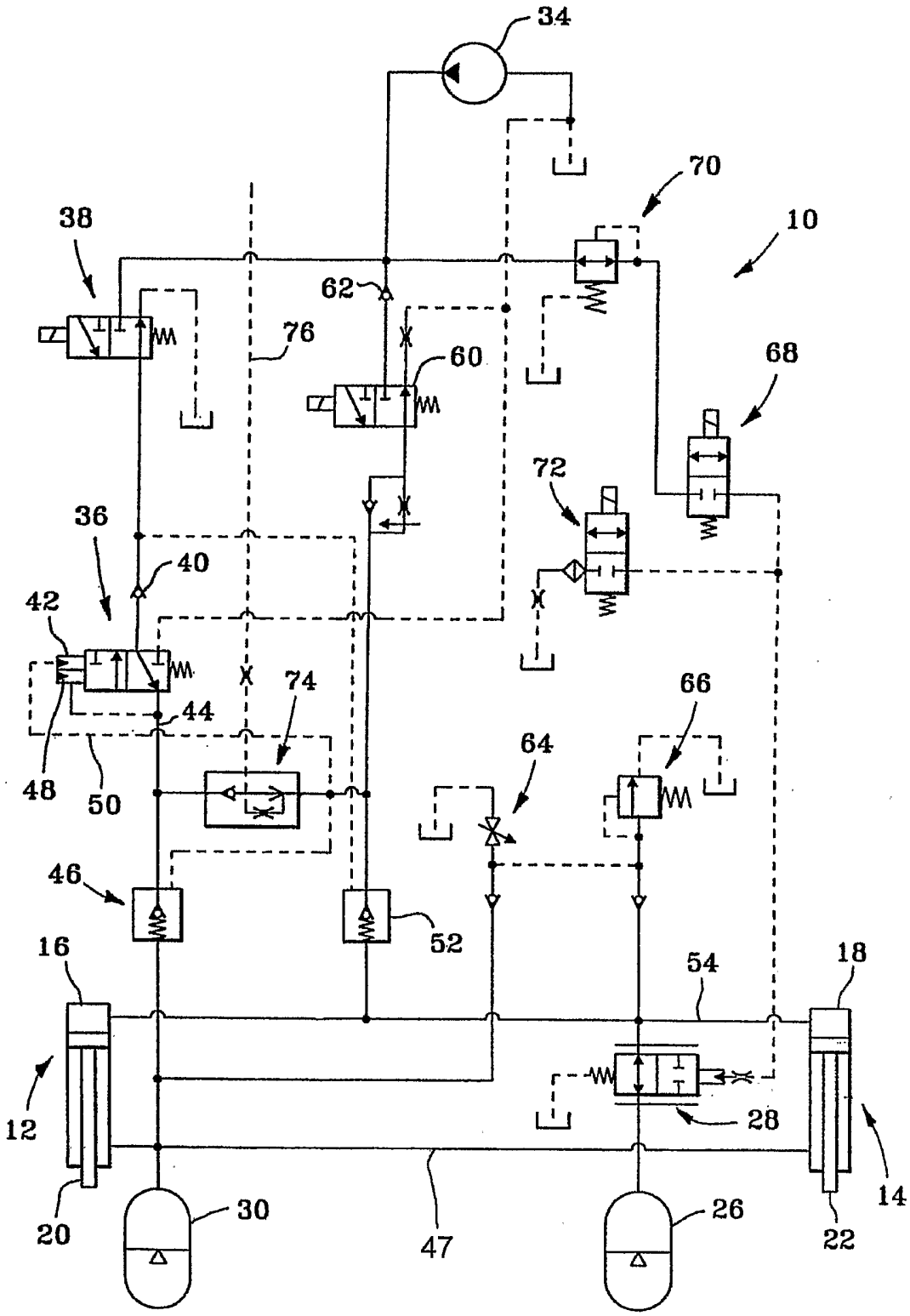
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 02/07550

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B60G17/04 B60G21/073 B60G17/056 B60G17/033

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)
IPC 7 B60G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	US 5 338 010 A (HAUPT JOSEF) 16 August 1994 (1994-08-16) column 1, line 60 -column 2, line 52; figures 1,2	1,2,6,7, 9 3-5 8
Y	US 6 145 859 A (HEIM WERNER ET AL) 14 November 2000 (2000-11-14) column 6, line 40 - line 51	3,4
Y	DE 42 42 448 C (INTEGRAL HYDRAULIK CO) 31 March 1994 (1994-03-31) column 3, line 30 - line 35; figure 1	5

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

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
1 October 2002	09/10/2002

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 02/07550

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