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(54) **METHOD FOR CONTROLLING AN OPEN CENTER ELECTRO-HYDRAULIC CONTROL VALVE, IN PARTICULAR FOR OPERATING AN ORGAN OF AN AGRICULTURAL OR WORK VEHICLE**

(57) Method of controlling an electro-hydraulic open center control valve (OCV) for the operation of a hydraulic actuator (ACT) of an organ (A, B) of a working or agricultural vehicle (VHE), powered by a pump (P), wherein a control signal of the control valve is generated proportionally to a position of a control lever (J), the method including a first step (Step 1) of detecting the exceeding of a predetermined position (DB) of the control lever (J) of the hydraulic organ, a second and consequent step (Step 2) of increasing and measuring a control signal value (Offset) at a staring movement of said hydraulic actuator and a third step (Step 3) of setting a positive offset to the control signal (LS) approximately equal to said control signal value, as long as the position of the control lever (J) of the hydraulic organ exceeds said predetermined position (DB).

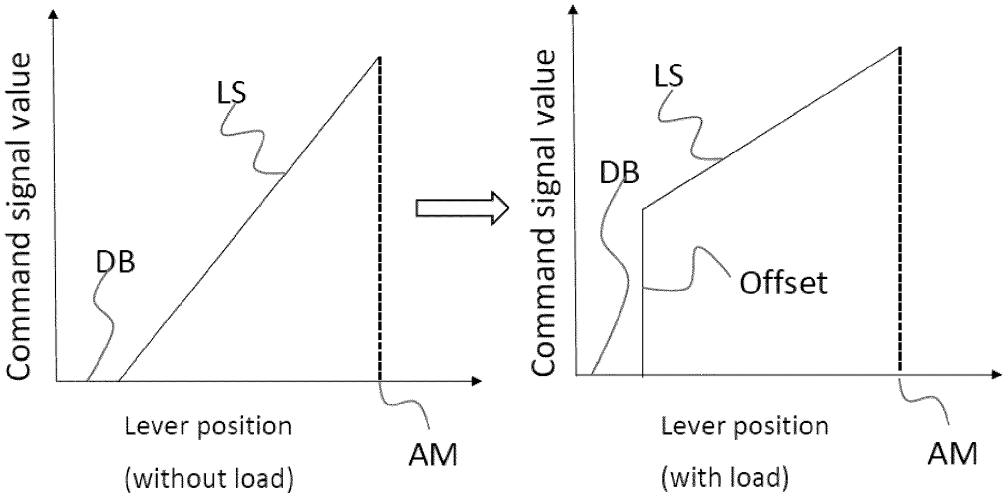

Fig. 5

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Description

Field of the invention

[0001] The present invention relates to the field of control methods for open center electro-hydraulic control valves, in particular for the actuation of an organ of an agricultural or work vehicle, generally equipped with a hydraulic circuit for the actuation of an actuator enslaved for the actuation of an organ such as an arm or a bucket and the like.

State of the art

[0002] The open center electro-hydraulic control valves are widely used in the field of operating machines and in particular in the field of agricultural and work vehicles for the control of the related hydraulic components such as arms and buckets.

[0003] Such valves are controlled by means of a current signal generated in proportion to the angular position of a control lever arranged, for example, in the vehicle cabin.

[0004] As a consequence of the current signal applied to the electro-hydraulic valve, a relative movable spool moves inside the valve, partitioning a first flow of hydraulic oil addressed to a hydraulic actuator and a second flow of hydraulic oil addressed to the hydraulic oil recovery tank T; in particular, when the spool is at a first end position of the relative displacement, the first flow is zero and the second flow is maximum, while when the spool is in a second end position opposite to the first one, the first flow is maximum and the second flow is zero.

[0005] A pump, generally with a fixed displacement, takes the hydraulic oil from the hydraulic tank T and pumps it into the hydraulic circuit that feeds the electro-hydraulic control valve.

[0006] Figures 1 and 2 show respectively an electro-hydraulic diagram and a block diagram of the known controls implementing electro-hydraulic open center control valves.

[0007] A problem with open-center control valves OCV is that the partitioning of the flows depends not only on the position of the spool, but also on the load applied to the hydraulic actuator.

[0008] This means that in relation to this load, the operator must start to operate the control lever of the hydraulic organ really slowly as long as the partitioning of the first and second flows is such that to balance the load. This means that there is no fixed relationship between the position of the organ control lever and the beginning of the movement of the organ itself.

[0009] It is clear that the load applied to the organ affects the relative hydraulic actuator, therefore it is equivalent referring to the load applied to the organ or its hydraulic actuator. It is also evident that the position of the actuator control lever affects the position of the movable spool, but this is not sufficient to ensure that the actuator and thus the relative member begins to move when the lever reaches a predetermined position. On the contrary, this means that the operator must gradually act on the control lever, until the organ begins to move, and then he can further adjust the progression of its movement.

[0010] In the first phase of "offset search", the operator must act gradually, as sudden actions could induce, once the position of the spool balances the load applied to the organ is exceeded, sudden, uncontrolled and potentially dangerous movements of the operated organ.

[0011] A known solution is to replace the open center control valve with a closed center electrohydraulic valve.

[0012] Closed center valves are much more complex and expensive.

[0013] If not specifically excluded in the detailed description below, what is described in this chapter is to be considered as an integral part of the detailed description.

Summary of the invention

[0014] The purpose of the present invention is to present a control method of an open center electro-hydraulic control valve, which overcomes the problems of the known art.

[0015] In other words, the main object of the present invention is to cause an open center valve to behave like a closed center valve.

[0016] The basic idea of the present invention is to implement a feedback control that identifies the offset of the control signal corresponding to the offset of the spool position, such as to balance the load, by means of the implementation of an associated position sensor to the hydraulic actuator. Obviously, the weight of the load varies from time to time and therefore the offset of the spool control signal must also vary accordingly.

[0017] In other words, the idea is to manipulate the signal generated by the control lever of the organ so that in a predetermined angular position of the control lever of the organ controlled by the lever begins to move regardless of the load applied to it.

[0018] Advantageously, a "drowback" in the open center valves is compensated through the control of the same, so that in practical terms, the operator control the hydraulic parts of an operating machine as in case the control valves of the relative actuators were of the closed type.

[0019] To avoid uncontrolled movements following the implementation of the present invention, a so-called dead band is provided, adjacent to the release position of the control lever of the controlled organ, in which the signal generated by the same lever is null or considered null, so that only when the dead band is exceeded, the calculation of the offset signal value to be applied to the signal generated by the control lever is triggered.

[0020] Since the amount of the load can vary even suddenly, for example because it is released, then the offset signal is reset when the lever is released or in any case when it enters the dead band.

[0021] The dependent claims describe preferred vari-

ants of the invention, forming an integral part of this description.

Brief description of figures

[0022] Further objects and advantages of the present invention will become clear from the following detailed description of an example of its embodiment (and its variants) and from the attached drawings given purely by way of non-limiting explanation, in which:

Figure 1 shows an electro-hydraulic diagram for controlling the operation of a hydraulic actuator of an organ (bucket or arm) of a work vehicle according to the known art;
in figure 2 the same diagram of figure 1 of the prior art is shown according to a block diagram, in which the dotted connectors indicate electrical control lines, while the continuous connectors indicate hydraulic lines;
Figure 3 shows an electro-hydraulic diagram for controlling the operation of a hydraulic actuator according to the present invention, based on the diagram in Figure 1;
Figure 4 shows a block diagram based on the diagram of Figure 2 and modified on the basis of the diagram of Figure 3 of the present invention;
Figure 5 shows the comparison between the graph of the control signal according to the present invention, as a function of a position of a control lever and as a function of the absence or presence of a load applied to the controlled actuator;
Figure 6 shows a flow chart representative of an implementation example of the method object of the present invention;
Figure 7 shows a work or agricultural vehicle implementing the method object of the present invention.

[0023] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0024] The blocks shown in hatched are optional.

[0025] It should also be noted that the terms "first", "second", "third", "upper", "lower" and the like can be used here to distinguish various elements. These terms do not imply a spatial, sequential or hierarchical order for the modified elements unless specifically indicated or inferred from the text.

[0026] The elements and features illustrated in the various preferred embodiments, including the drawings, can be combined with each other without however departing from the scope of this application as described below.

Detailed description of exemplary embodiments

[0027] With reference to Figures 3 and 4, a position sensor SS is associated with the hydraulic actuator ACT controlled by the open center control valve OCV and when from a release condition the control lever J reaches the limit of the dead band DB, then it is increased control signal OCV of the control valve until actuator ACT movement is detected by the sensor SS. Then, the signal value is stored and added stably to the signal generated by the control lever.

[0028] Therefore, the control method of the open center electro-hydraulic control valve OCV for operating a hydraulic actuator ACT of an organ A, B of a work or agricultural vehicle VHE, powered by a pump P, in which a signal of control of the control valve is generated in proportion to a position of a control lever J,
the method, with reference to Figure 6, comprises

- a first step (Step 1) to detect the exceeding of a predetermined position DB of the control lever J of the hydraulic unit,
- a second and consequent step Step 2 of increasing and measuring a control signal value (Offset) causing a staring movement of said hydraulic actuator and
- a third step (Step 3) to set a positive offset to the control signal LS approximately equal to said value, as long as the position of the control lever J of the hydraulic organ exceeds said predetermined position DB.

With reference to Figure 4, the second step is a closed loop control in which the feedback variable consists of the movement start of the hydraulic actuator. In fact, all the signals converge in the processing unit CPU which receives the signal generated by the control lever J at its input and generates an increase in the valve control signal based on the position signal received from the position sensor SS. The AMP block representing a signal amplifier is voluntarily represented as external to the CPU block to make the invention easier to understand, but it must be clear that the entire method object of the present invention can be entirely implemented in the processing unit CPU.

[0029] Figure 5 shows a comparison of the control signal generated by the block AMP in two different conditions, i.e. when the organ, for example the arm of a loader, is lifted without load (left in figure 5) or if it is lifted with load (on the right in figure 5).

[0030] When the load is not applied, the behavior of the control is completely identical to what occurs according to the known art.

[0031] Conversely, in the case of applied load, the intensity of the command signal is manipulated by adding the Offset value calculated in step 2, while the remaining portion LS of the curve is connected, for example linearly, from the Offset value in DB up to the maximum value of the control signal in AM, which represents the position of maximum inclination of the control lever J.

[0032] It is worth highlighting that if the original curve, i.e. without load, is not linear, for example hyperbolic or parabolic, the same behavior can be maintained after the

application of the Offset, taking into account that the maximum value of the signal applied to the valve must remain unchanged to avoid damaging the valve.

[0033] In other words, the overall control signal of the control valve is the sum of a first contribution given by the offset (positive), calculated in DB, and a second LS contribution proportional to the current position of the control lever.

[0034] Preferably, each time the lever returns to the release position or in the dead band, a fourth step (Step 4) is performed to cancel the previously stored control signal value (Offset) to start over from the first step, i.e. from the beginning of this method.

[0035] It is worth noting that the processing unit is extremely fast by performing a significant number of calculation cycles in the time unit, therefore, the offset calculation is almost instantaneous. However, the increase in the command signal value up to the detection of the actuator displacement can be linear or follow different laws to make this identification of the Offset even faster.

[0036] For example some laws can be exponential or parabolic.

[0037] According to a preferred variant of the invention, it is also taken into account that the flow of hydraulic liquid entering the open center electro-hydraulic control valve OCV can vary.

[0038] With high flow rates of hydraulic liquid, small displacements of the movable spool can induce large actuator movement, therefore it is advisable that the law of increasing the command signal carried out during the second step for searching the Offset value is inversely proportional to the hydraulic liquid flow generated by the hydraulic fluid source.

[0039] Generally, the hydraulic source is a pump driven by the prime mover, which typically is an internal combustion engine, therefore, the law of increasing the drive signal of the movable spool in step 2 can have a progression inversely proportional to the flow generated by the hydraulic source or equivalently to the speed of rotation of the prime mover which drives the hydraulic pump which feeds the control valve OCV.

[0040] The present invention can be advantageously realized by means of a computer program which comprises coding means for carrying out one or more steps of the method, when this program is executed on a computer. Therefore it is intended that the scope of protection extends to said computer program and further to computer readable means comprising a recorded message, said computer readable means comprising program coding means for carrying out one or more steps of the method. , when said program is run on a computer.

[0041] Implementation variants of the described non-limiting example are possible, without however departing from the scope of protection of the present invention, including all the equivalent embodiments for a person skilled in the art, to the content of the claims.

[0042] From the above description the person skilled in the art is able to realize the object of the invention without introducing further construction details.

Claims

1. Method of controlling an electro-hydraulic open center control valve (OCV) for the operation of a hydraulic actuator (ACT) of an organ (A, B) of a working or agricultural vehicle (VHE), powered by a pump (P), wherein a control signal of the control valve is generated proportionally to a position of a control lever (J),
   the method including

   - a first step (Step 1) of detecting the exceeding of a predetermined position (DB) of the control lever (J) of the hydraulic organ,
   - a second and consequent step (Step 2) of increasing and measuring a control signal value (Offset) at a staring movement of said hydraulic actuator and
   - a third step (Step 3) of setting a positive offset to the control signal (LS) approximately equal to said control signal value, as long as the position of the control lever (J) of the hydraulic organ exceeds said predetermined position (DB).

2. Method according to claim 1, wherein said second step is performed by means of a closed loop control wherein the feedback variable consists in said movement of said hydraulic actuator.

3. Method according to any one of the preceding claims, wherein the overall control signal of the control valve is the sum of a first contribution given by said positive offset and a second contribution (LS) proportional to the current position of the control lever.

4. Method according to any one of the preceding claims, provides for a fourth step of erasing said control signal value (Offset) after returning the control lever to a position lower than said predetermined position (DB) and repeating the method from its Start.

5. Method according to any one of the preceding claims, wherein said second step comprises increasing said signal value according to a linear or exponential or parabolic trend.

6. Method according to any one of the preceding claims, wherein said increase has a progression inversely proportional to a flow rate generated by a source of hydraulic liquid feeding said control valve.

7. Method according to any one of the preceding claims 1 to 5, wherein said increase has a progression inversely proportional to a speed of rotation of a prime

mover arranged to drive into rotation a hydraulic pump feeding said control valve.

8. Computer program comprising program coding means adapted to carry out all steps (i - iv) of any one of claims 1 to 7, when said program is run on a computer.

9. Computer readable means comprising a recorded program, said computer readable means comprising program coding means adapted to perform all steps (i - iv) of any one of claims 1 to 7, when said program is run on a a computer.

10. Control system of an electro-hydraulic open center control valve (OCV) for operating a hydraulic actuator (ACT) of an organ (A, B) of a work or agricultural vehicle, powered by a pump (P), the system comprising

- a control lever (J) configured to generate a first signal proportional to a position of the control lever,
- processing means (CPU, AMP) arranged to generate a control signal (LS) of the control valve, proportionally to said first signal,
- detection means (SS) arranged to detect a movement of said hydraulic actuator as a result of the application of said command signal,
- wherein the processing means (CPU) operatively connected with said detection means and configured to detect the overcoming of a predetermined position (DB) of the control lever (J) of the hydraulic member and consequent to increase and measure a signal control value (Offset) at the starting of a movement of said hydraulic actuator and then to set a positive offset to the control signal (LS) approximately equal to said control signal value, as long as the position of the control lever (J) of the hydraulic member exceeds said predetermined position (DB).

11. Agricultural or work vehicle comprising an organ (A, B) and a relative hydraulic actuator (ACT) and a control system of an electro-hydraulic open center control valve (OCV) for operating the hydraulic actuator (ACT), wherein the control system conforms to claim 10.

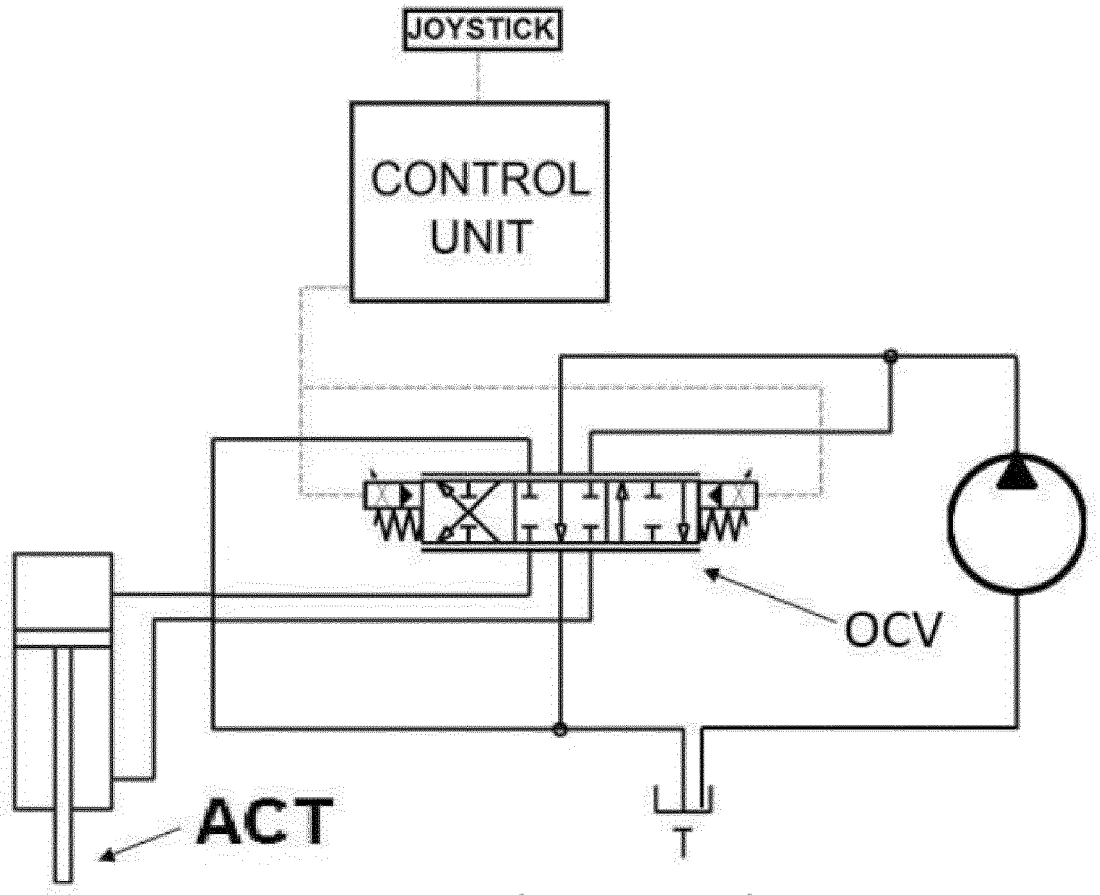

Fig. 1 (prior art)

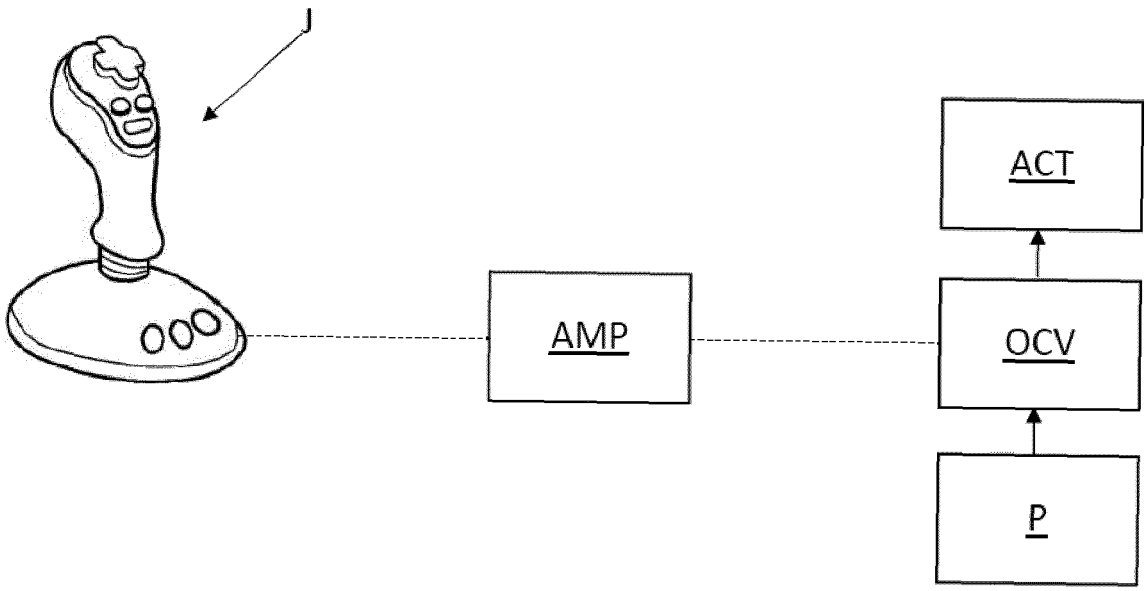

Fig. 2 (prior art)

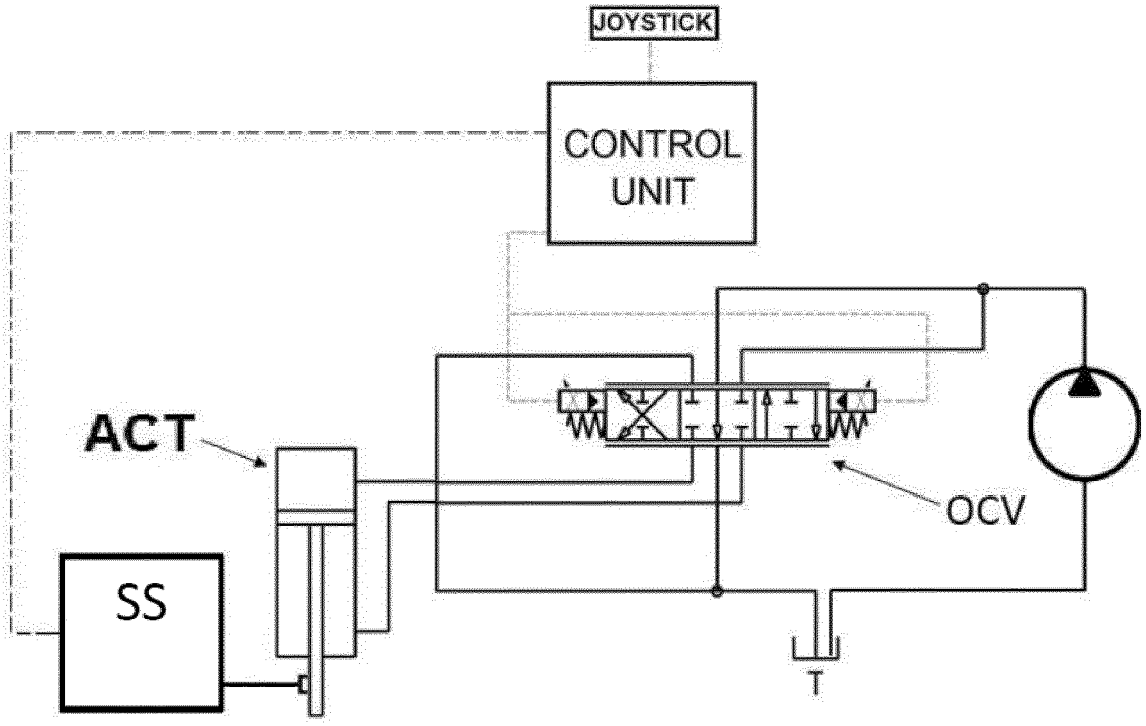

Fig. 3

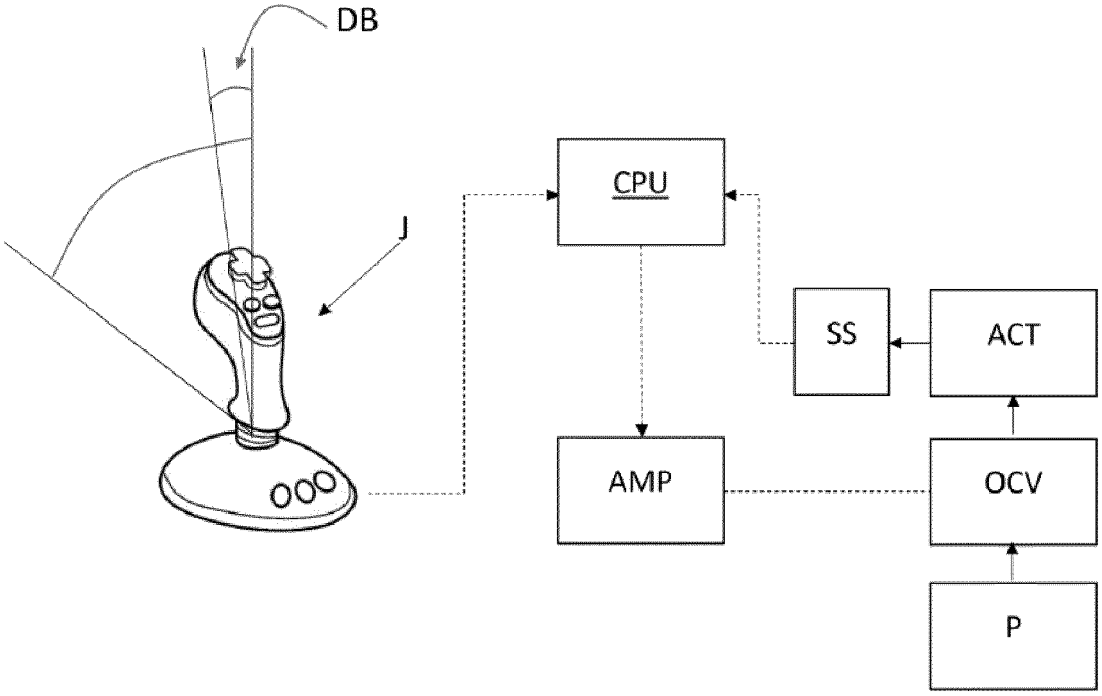

Fig. 4

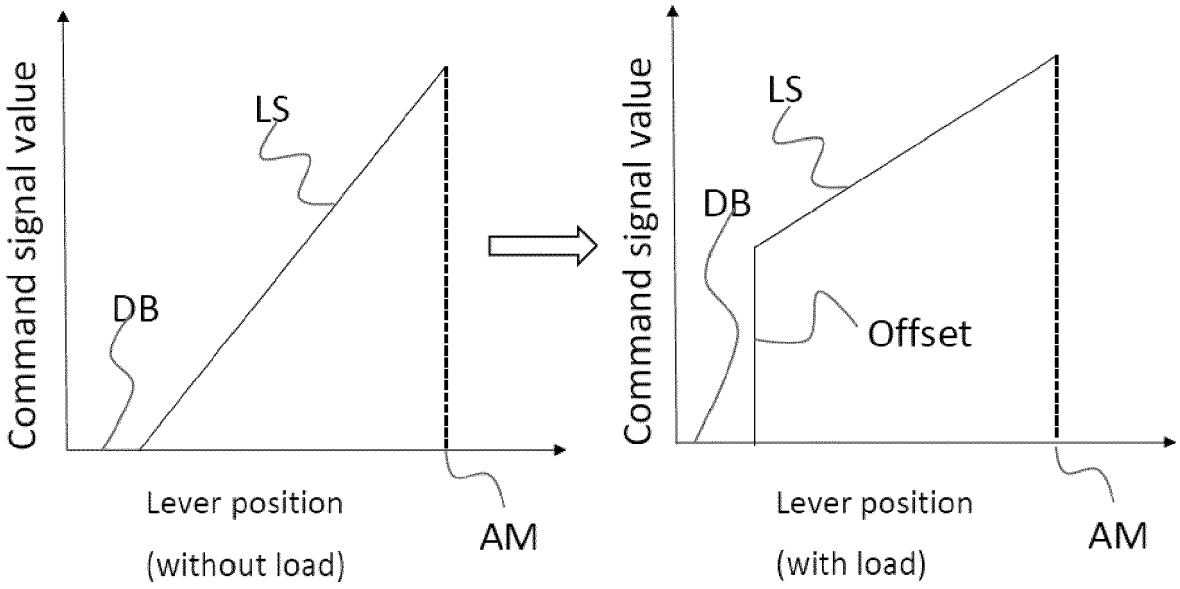
Command signal value
LS
DB
Lever position
(without load)
AM
Command signal value
LS
DB
Offset
Lever position
(with load)
AM

Fig. 5

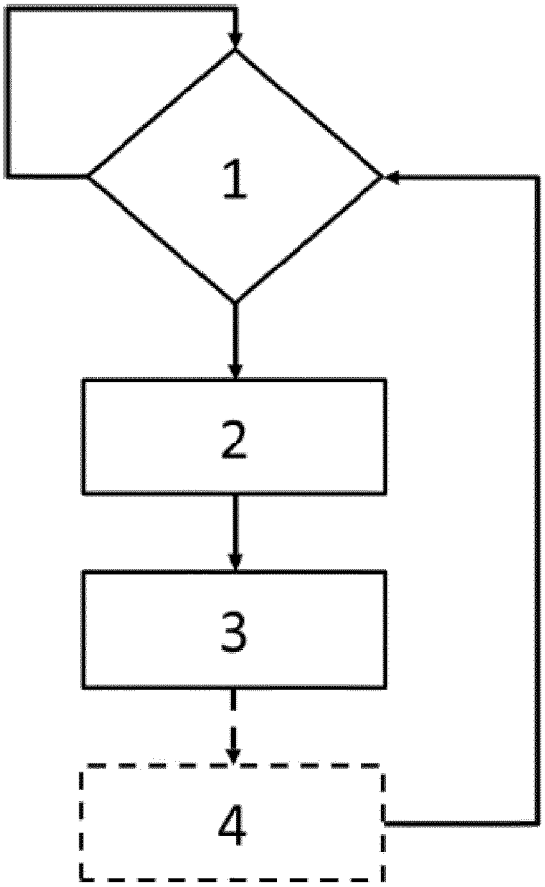

Fig. 6

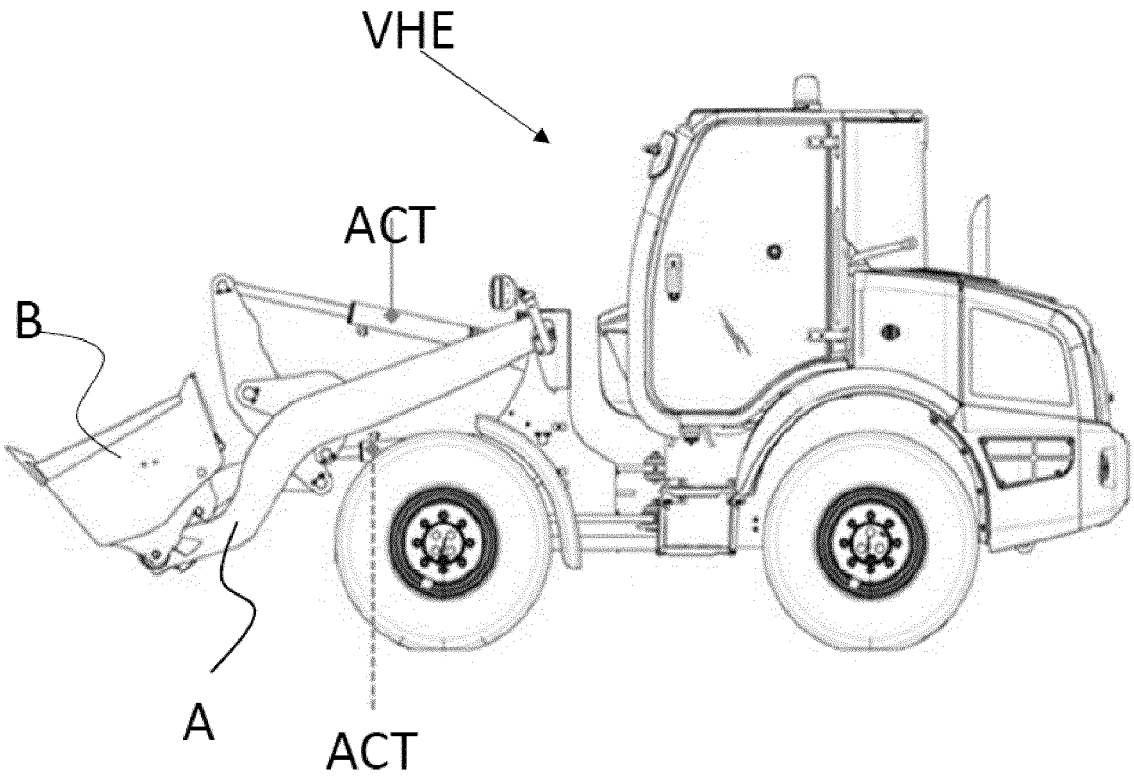

Fig. 7

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EUROPEAN SEARCH REPORT

Application Number
EP 21 20 6690

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2019/050064 A1 (VOLVO CONSTR EQUIP AB [SE]; SHIN HUNGJU [KR]) 14 March 2019 (2019-03-14) * paragraphs [0009], [0026], [0035], [0052]; figures 3,4,5,6; examples 160,150,140,130,120 *	1-11	INV. F15B11/08 F15B19/00
A	US 6 615 114 B1 (SKIBA RICHARD J [US] ET AL) 2 September 2003 (2003-09-02) * column 7, lines 19-56; figure 2; examples 24`, 28`,44`,14`,32`,26` *	1-11	
A	US 6 401 456 B1 (MORIYA NAOYUKI [JP] ET AL) 11 June 2002 (2002-06-11) * Steps 2,7 Fig.3; figures 3,5,4,1,2 *	1-11	
A	US 7 512 460 B2 (CNH AMERICA LLC [US]) 31 March 2009 (2009-03-31) * column 4, lines 9-24; figures 3,1,5,4,6; examples 26,24,34,30,32,22 *	1-11	

TECHNICAL FIELDS SEARCHED (IPC)
F15B

1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	8 March 2022	Deligiannidis, N

CATEGORY OF CITED DOCUMENTS

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08-03-2022

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