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(54) A CONTROL METHOD OF ACTUATING A MOVEMENT OF AT LEAST ONE OF A BOOM AND AN IMPLEMENT CONNECTED TO THE BOOM IN A WORK VEHICLE, A CORRESPONDING CONTROL SYSTEM AND A WORK VEHICLE COMPRISING SUCH CONTROL SYSTEM

(57) A control method for actuating a soft stop movement of at least one of a boom and an implement connected to the boom in a work vehicle is disclosed. Actuating the boom and the implement occurs by means of a joystick controlled by a user, a movement of the joystick in a predetermined control area according to a first preset direction causing the actuation of the boom by a first hydraulic actuator and a movement of the joystick in the control area according to a second preset direction causing the actuation of the implement by a second hydraulic actuator. Each hydraulic actuator includes a respective open centre directional solenoid valve whose opening degree is controlled by means of a driving current as a function of a the position of the joystick. The control method comprises detecting a travel of the joystick from a driving region to a predetermined neutral region, measuring a neutral time in which the joystick position is continuously inside the neutral region, and if the neutral time is greater than a predetermined threshold of time, controlling the driving current so that it reaches zero with a derivative over time reaching with continuity a value which is lower than a predetermined rate threshold value.

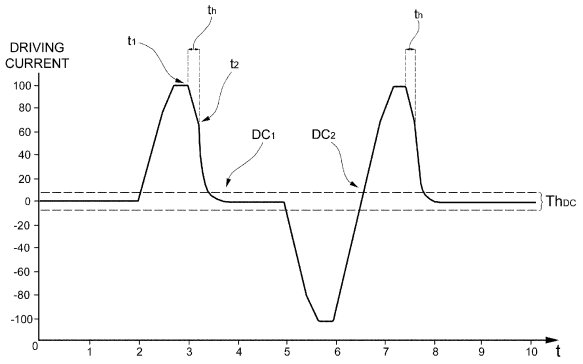

FIG.5

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Description

Technical field

[0001] The present invention relates generally to a work vehicle, such as for example a compact wheel loader, and particularly to a control method of actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle and to a corresponding control system.

Prior art

[0002] Motorized work vehicles are well known for use in material handling that carry an implement and have a hydraulically operated lifting arm for moving the implement. Examples of such vehicles are tractors and loaders.

[0003] A loader is a heavy equipment machine used in construction to move aside on the ground or load materials such as asphalt, demolition debris, dirt, snow, feed, gravel, logs, raw minerals, recycled material, rock, sand, woodchips, etc. into or onto another type of machinery (such as a dump truck, conveyor belt, feed-hopper, or railroad car). There are many types of loader, which, depending on design and application, are called by various names, including bucket loader, front loader, front-end loader, payloader, scoop, shovel, skip loader, wheel loader, or skid-steer. In particular, compact wheel loaders are compact vehicles that have road wheels and carry a working implement, such as a bucket, attached to a lift arm or boom, that is hydraulically powered.

[0004] Referring to figure 1, a work vehicle 1, such as a compact wheel loader, is shown. However, the invention is not limited to such a kind of work vehicle, but is applicable to any other kind of work vehicle.

[0005] A compact wheel loader includes a bucket 2 connected to a frame 3 of the work vehicle for movement relative thereto. As shown, a pair of booms 5 (only one being shown) is each pivotally connected at one end on opposite sides of frame 3. The bucket 2 is pivotally connected at the opposite end of booms for tilting movement relative to the frame 3 about a generally horizontal axis. The above-described features form no substantial part of the present invention and are generally well known in the art. A bucket may be replaced in operation by any other implement or attachment.

[0006] Usually, the movement of the boom 5 and of the bucket 2 is controlled by the user through a joystick 7 placed inside an operator's cab or cabin 9 of the work vehicle 1.

[0007] As can be seen in figure 2, which shows a control diagram of the work vehicle 1, the boom 3 and the bucket 2 are moved by an hydraulic control circuit 10 comprising a first and a second hydraulic actuators 12, 14 which are controlled by an electronic control unit 16 through respective solenoid valves 18, 20 according to the position of the joystick 7 controlled by the user.

[0008] Load-sensing valves allow a pressure compensation so that downstream channels take proportional allocation of flow depending on the load. The flow rate at a predetermined opening degree is not dependent upon the load downstream each valve and is not dependent upon the pump inlet flow. When a plurality of loads is actuated, load-sensing valves with flow sharing also prevent the working fluid from taking the path of least resistance. However, this solution is very expensive. Advantageously, open centre directional solenoid valves are less expensive than load-sensing valves. Disadvantageously, in open centre directional solenoid valves the flow rate at a predetermined opening degree is dependent upon the pump inlet flow, the number of valves supplied by the pump and the load downstream each valve.

[0009] For example, each hydraulic actuator comprises an hydraulic cylinder operatively connected respectively to the boom and the implement, that uses hydraulic power of a working fluid to facilitate mechanical operation, the working fluid being controlled by means of open centre directional solenoid valves 18, 20. As liquids are nearly impossible to compress, a hydraulic actuator can exert a large force. The rate of actuation of the boom and implement is controlled by the opening degree of the respective open centre directional solenoid valve 18, 20 by means of a driving current thereof as a function of the position of the joystick.

[0010] The hydraulic flow rate of the working fluid required to operate the boom and the implement is produced by a hydraulic fixed displacement pump P connected to a fluid reservoir T and driven by an internal combustion engine or an electrical motor M (hereinafter simply referred to as motor) of the vehicle, e.g. by a mechanical linkage. Therefore, the rate of movement of the boom and the implement at a predetermined joystick position is dependent upon the motor rotational speed. For instance, when the motor is working at a high motor rotational speed, it is necessary a minimum movement of the joystick by the user to start the movement of the boom and/or the implement. On the contrary, when the motor is working at a low motor rotational speed, it is necessary a large movement of the joystick by the user to start the movement of the boom and/or the bucket.

[0011] Figure 3 shows an exemplary joystick of a work vehicle. A movement of the joystick in an associated bi-dimensional control area A according to a first direction y causes the actuation of the boom and a movement of the joystick in said control area A according to a second direction x causes the actuation of the implement. The intersection of said x and y directions is defined as origin O of the control area A, and corresponds to the neutral position of the joystick.

[0012] A neutral region N around the neutral position of the joystick is a region where the boom and implement are not actuated. A region externally surrounding the neutral region is defined a driving region and indicated D in this figure.

[0013] For example, according to the orientation de-

picted in figure 3, in an embodiment where the implement is a bucket, when the joystick is moved up from the origin O of the control area A according to the y direction the boom is is lowered towards ground and when the joystick is moved down from the origin O according to the y direction the boom is lifted with respect to ground. Further, when the joystick is moved right from the origin O according to the x direction the implement, e.g. the bucket, is tilted towards a dumping position, and when the joystick is moved left from the origin O according to the x direction the implement, e.g. the bucket, is tilted towards a dig position and beyond.

[0014] A combination of movement in both directions x and y of the joystick is allowed in order to move simultaneously the boom and the bucket.

[0015] When the user fastly releases the joystick in the neutral region without guiding it to the neutral position, the driving current controlling the opening degree of the open centre directional valve rapidly goes to zero and closes the valve. As a consequence, the boom and/or the implement is roughly stopped, and this may cause an undesired loss of material from the bucket.

[0016] A further drawback is that when the boom and/or the implement is suddenly stopped the operator's cab 9 of the work vehicle is subject to shocks and vibrations. These shocks and vibrations are transmitted to the user and produce noise in the cab, thus generating discomfort to the user.

Summary of the invention

[0017] The aim of the present invention is to provide a solution that avoids the drawbacks of the prior art. Particularly, an aim of the present invention is to improve the controllability of a boom and/or implement in a work vehicle when a user fastly releases the joystick in the neutral region. A further aim of the present invention is to increase the comfort of the user when such manoeuvre occurs.

[0018] According to the invention, this aim is achieved by a control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle, having the features claimed in claim 1.

[0019] Preferred embodiments are defined in the dependent claims, whose content is also to be considered an integral part of the present description. Features of the dependent claims may be combined with the features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0020] Further subjects of the invention are a control system for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle, as well as a work vehicle, as claimed.

[0021] In summary, an actuation strategy of a boom and/or an implement of a work vehicle is disclosed according to which, based on information about the joystick position - that can be retrieved as an electronic signal provided by a position sensor associated with the joystick - actuation is controlled by recognizing if the user has released the joystick to the neutral region and, in the affirmative, by applying a predetermined first order filter to the driving current of the open centre directional solenoid valves of the hydraulic actuating means of the boom and the implement, in order to get a smooth stop thereof.

Brief description of the drawings

[0022] Further functional and structural characteristics and advantages of the present invention are set out in the detailed description below, provided purely as a non-limiting example, with reference to the attached drawings, in which:

- figure 1 shows a prior art exemplary work vehicle, in particular a compact wheel loader;
- figure 2 shows a prior art control diagram of a work vehicle;
- figure 3 shows a prior art exemplary joystick of a work vehicle;
- figure 4 shows a curve indicating the exemplary movement of the joystick of the work vehicle in a direction of movement in two separate manoeuvres; and
- figure 5 shows a curve representing the driving current of an open centre directional solenoid valve of an hydraulic actuator for a boom or an implement corresponding to the movement of the joystick illustrated in figure 4, according to the invention.

Detailed description

[0023] In the following description, unless otherwise defined, all terms (including technical and scientific terms) are to be interpreted as is customary in the art. It will be further understood that terms in common usage should also be interpreted as is customary in the relevant art and not in an idealized or overly formal sense unless expressly so defined herein. All orientation terms, such as upper and lower, are used in relation to the drawings and should not be interpreted as limiting the invention.

[0024] In the following, a preferred embodiment of a control method for actuating a movement of at least one of a boom and an implement connected to the boom in a work vehicle is described. Reference is made to the control diagram of Figure 2 that has been previously described, and the electronic control unit 16 is configured to implement the control method of the invention.

[0025] As disclosed above and with further reference to Figure 3, actuation of the boom 5 and the implement 2 occurs by means of joystick 7 controlled by a user, whose movement in the control area A according to direction y causes the actuation of the boom 5 by first hydraulic actuating means 12 and whose movement in the control area A according to direction x causes the actuation of the implement 2 by second hydraulic actuating means 14.

[0026] Each hydraulic actuating means 12, 14 include an hydraulic cylinder operatively connected respectively to the boom 5 and the implement 2, and a respective first and second open centre directional solenoid valve 18, 20 whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder.

[0027] The rate of actuation of the boom 5 is controlled by the opening degree of the first open centre directional solenoid valve 18 by means of the driving current thereof as a function of a first component of the position P of the joystick 7 along direction y in the control area A. The rate of actuation of the implement 2 is controlled by the opening degree of the second open centre directional solenoid valve 20 by means of the driving current thereof as a function of a second component of the position P of the joystick 7 along direction x in the control area A. The first component of the position P of the joystick 7 along direction y is indicated y_P in figure 3 and is the projection over y axis of a vector representing the position P of the joystick in the control area A. The second component of the position P of the joystick 7 along direction x is indicated x_P in figure 3 and is the projection over x axis of the vector representing the position P of the joystick in the control area A.

[0028] The electronic control unit 16 has input means adapted to receive at least a signal S_J indicative of a position of the joystick in the control area, and output means adapted to issue at least a signal S_{DC} indicative of a driving current intended to control an opening degree of the open centre directional solenoid valve 18, 20.

[0029] The electronic control unit 16 is configured to detect a travel of the joystick 7 in control area A from a driving region D to neutral region N.

[0030] When the electronic control unit detects that the current joystick position enters the neutral region N, a neutral time is measured during which the joystick position is continuously inside the neutral region, i.e. each time the joystick exits the neutral region, such as in a manoeuvre of inverting the actuation of the boom or implement, the measurement of the time is resetted.

[0031] If the measured neutral time is greater than a predetermined threshold of time Th, that may be set by the manufacturer, the electronic control unit 16 performs a controlling strategy of the driving current of the valves controlled according to the joystick (x/y axis) position according to the invention. More preferably, the controlling strategy of the driving current is applied to both valves 18, 20 depending on the joystick position in the driving region.

[0032] Specifically, the driving current is controlled so that said driving current reaches zero with a derivative over time reaching with continuity a value which is lower than a predetermined rate threshold value in absolute terms.

[0033] With reference to figure 4, it is shown an exemplary curve indicating the movement of the joystick of the work vehicle in a predetermined direction of movement which may be along x axis or y axis or a combination of the two. For example, this curve is indicating the movement of the joystick according to the y direction whereby in a first manoeuvre the boom 5 is lowered from a first position relative to ground to a second, lower position relative to ground, and in a second manoeuvre the boom 5 is lifted from a first position relative to ground to a second upper position relative to ground and subsequently lowered to a third position relative to ground without stopping its movement.

[0034] Referring to figure 5, it is shown a curve indicating the evolution of the driving current of the first open centre directional solenoid valve 18 actuating the boom 5 according to the first manoeuvre and the second manoeuvre of the joystick illustrated in figure 4, the driving current being controlled by the electronic control unit.

[0035] In the first manoeuvre the joystick 7 is first moved from the neutral region N to an operating position DP in the driving region D, where it is held for an actuation time interval. Then, the joystick is moved back to the neutral region where it is left resting for a prolonged time at the end of the manoeuvre. When the joystick reaches the neutral region N along a travel from the operating position DP, which is represented in the figure by the segment J_1 of the curve, the electronic control unit 16 checks whether the position of the joystick inside the neutral region N is maintained for at least the predetermined threshold of time Th. According to this exemplary manoeuvre, the position of the joystick inside the neutral region N is maintained for a time greater than the predetermined threshold of time Th.

[0036] Referring to the driving current curve depicted in Figure 5, the electronic control unit detects that the current joystick position enters the neutral region N at time t_1. Since the position of the joystick inside the neutral region N is maintained for a time greater than the predetermined threshold of time Th, i.e. the neutral time is greater than Th, the electronic control unit acquires this information at time t_2 and consequently starts a soft stop procedure according to the invention. In the soft stop procedure the driving current is controlled by applying a predetermined first order filter so as to reach zero with a derivative over time reaching with continuity a zero value in a region DC_1 of the curve.

[0037] In the second manoeuvre the joystick 7 is first moved from the neutral region N to a first operating position DP' in the driving region D, where it is held for a first actuation time interval. Then, the joystick is moved to a second operating position DP" passing through the neutral region, e.g. in an area of the driving region lying substantially along the same direction followed to reach the operating position DP', but opposite to the neutral position, without stopping at the neutral position, and it is held there for a second actuation time interval. When the joystick passes through the neutral region N along a travel from the operating position DP' to the operating position DP", which is represented in the figure by the segment J_2 of the curve, the electronic control unit 16 checks whether the position of the joystick inside the neu-

tral region N is maintained for at least the predetermined threshold of time Th. According to this exemplary manoeuvre, the position of the joystick inside the neutral region N is maintained for a time smaller than the predetermined threshold of time Th. Finally, the joystick is moved to the neutral region where it is left resting for a prolonged time at the end of the manoeuvre. When the joystick reaches the neutral region N along a travel from the operating position DP'', which is represented in the figure by the segment J_3 of the curve, the electronic control unit 16 checks whether the position of the joystick inside the neutral region N is maintained for at least the predetermined threshold of time Th. According to this exemplary manoeuvre, the position of the joystick inside the neutral region N is maintained for a time greater than the predetermined threshold of time Th.

[0038] Referring to the driving current curve depicted in Figure 5, the electronic control unit detects that the current joystick position enters the neutral region N during the travel J_2, but since the position of the joystick inside the neutral region N is maintained for a time smaller than the predetermined threshold of time Th, the electronic control unit does not start a soft stop procedure according to the invention, and it controls the driving current in a way that is proportional to the continuously changing joystick position in a region DC_2 of the curve. When the joystick reaches the neutral region N along a travel represented in figure 4 by the segment J_3 of the curve, the electronic control unit detects that the joystick position enters the neutral region N and that its position inside the neutral region N is maintained for a time greater than the predetermined threshold of time Th, in a manner analogous to the first manoeuvre. Consequently, the electronic control unit starts a soft stop procedure according to the invention, where the driving current is controlled by applying a predetermined first order filter so as to reach zero with a derivative over time reaching with continuity a zero value.

[0039] In an alternative embodiment, the requirement that the driving current be controlled so as to reach zero with a derivative over time reaching with continuity a zero value may be relaxed, and the driving current is controlled so as to reach a near-to-zero value lower than a predetermined current threshold value Th_{DC} in absolute terms. In an alternative embodiment, that may be combined with the above, the driving current is controlled so as to reach zero or a near-to-zero value with a derivative over time reaching with continuity a value different from zero but which is lower than a predetermined rate threshold value in absolute terms.

[0040] Where the present invention has been described referring to a joystick configured to be operated by movement in a bi-dimensional control area combining the actuation of the boom and the actuation of the implement, it would be clear to a skilled person that a pair of independent joysticks or levers movable along respective, separate unidimensional control tracks are comprised within the scope of the invention as an equivalent embodiment, the principle of the invention being the same.

[0041] Therefore, by virtue of the present invention, a smooth operation of a boom and/or an implement of a work vehicle is achieved when a user fastly releases the joystick in the neutral region by means of an actuation strategy based on information about the joystick position and the time it remains within the neutral position, that is indicative of a release to neutral of the joystick.

[0042] The example embodiments are described in sufficient detail to enable those of ordinary skill in the art to implement a control system in a work vehicle arranged to carry out the disclosed control method herein described.

[0043] Naturally, the principle of the invention remaining unchanged, the embodiments and the constructional details may vary widely from those described and illustrated purely by way of non-limiting example, without thereby departing from the scope of the invention as defined in the appended claims.

Claims

1. A control method for actuating a soft stop movement of at least one of a boom and an implement connected to the boom in a work vehicle,

wherein actuating the boom and the implement occurs by means of a joystick controlled by a user, a movement of the joystick in a predetermined control area according to a first preset direction causing the actuation of the boom by first hydraulic actuating means and a movement of the joystick in said control area according to a second preset direction causing the actuation of the implement by second hydraulic actuating means,

wherein the first hydraulic actuating means and the second hydraulic actuating means each include an hydraulic cylinder operatively connected respectively to the boom and the implement, and a respective first and second open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder,

the rate of actuation of the boom being controlled by the opening degree of the first open centre directional solenoid valve by means of a driving current thereof as a function of a first component of the position of the joystick along said first preset direction in the control area, and the rate of actuation of the implement being controlled by the opening degree of the second open centre directional solenoid valve by means of a driving current thereof as a function of a second component of the position of the joystick along said second preset direction in the control area,

the control method comprising the steps of:

a) detecting a travel of the joystick in said control area from a driving region of the control area to a predetermined neutral region of the control area around a neutral position of the joystick;
b) measuring a neutral time in which the joystick position is continuously inside said predetermined neutral region; and
c) if the neutral time is greater than a predetermined threshold of time, controlling the driving current of at least one of said first open centre directional solenoid valve and said second open centre directional solenoid valve, so that said driving current reaches zero with a derivative over time reaching with continuity a value which is lower than a predetermined rate threshold value in absolute terms.

2. The control method according to claim 1, wherein said value is zero.

3. The control method according to claim 1 or 2, wherein said predetermined neutral region is a region around a position of intersection of said first and second preset directions, and said driving region is a region surrounding said neutral region.

4. The control method according to any one of the preceding claims, comprising at step c) controlling the driving current of both the first open centre directional solenoid valve and the second open centre directional solenoid valve, depending on the joystick position in the driving region.

5. A control system for actuating a soft stop movement of at least one of a boom and an implement connected to the boom in a work vehicle, comprising:

- input means adapted to receive at least a signal indicative of a position in a control area of a joystick controlled by a user for actuating the boom and the implement;
- output means adapted to issue at least a signal indicative of a driving current intended to control an opening degree of at least an open centre directional solenoid valve of hydraulic actuating means of said at least one of a boom and an implement,

the system being arranged to carry out a control method according to any one of claims 1 to 4.

6. Work vehicle, in particular compact wheel loader, comprising

- a boom and an implement connected to the boom;
- a joystick operatively controlled by a user for actuating the boom and the implement, the joystick being movable in a predetermined control area according to a first preset direction for actuating the boom and in a second preset direction for actuating the implement,
- first hydraulic actuating means for actuating the boom and second hydraulic actuating means for actuating the implement, wherein the first hydraulic actuating means and the second hydraulic actuating means each include an hydraulic cylinder operatively connected respectively to the boom and the implement, and a respective first and second open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid to the respective hydraulic cylinder, the opening degree of said first and second open centre directional solenoid valve being operatively controlled by means of a respective driving current; and
- a control system for actuating the soft stop movement of at least one of the boom and the implement, according to claim 5.

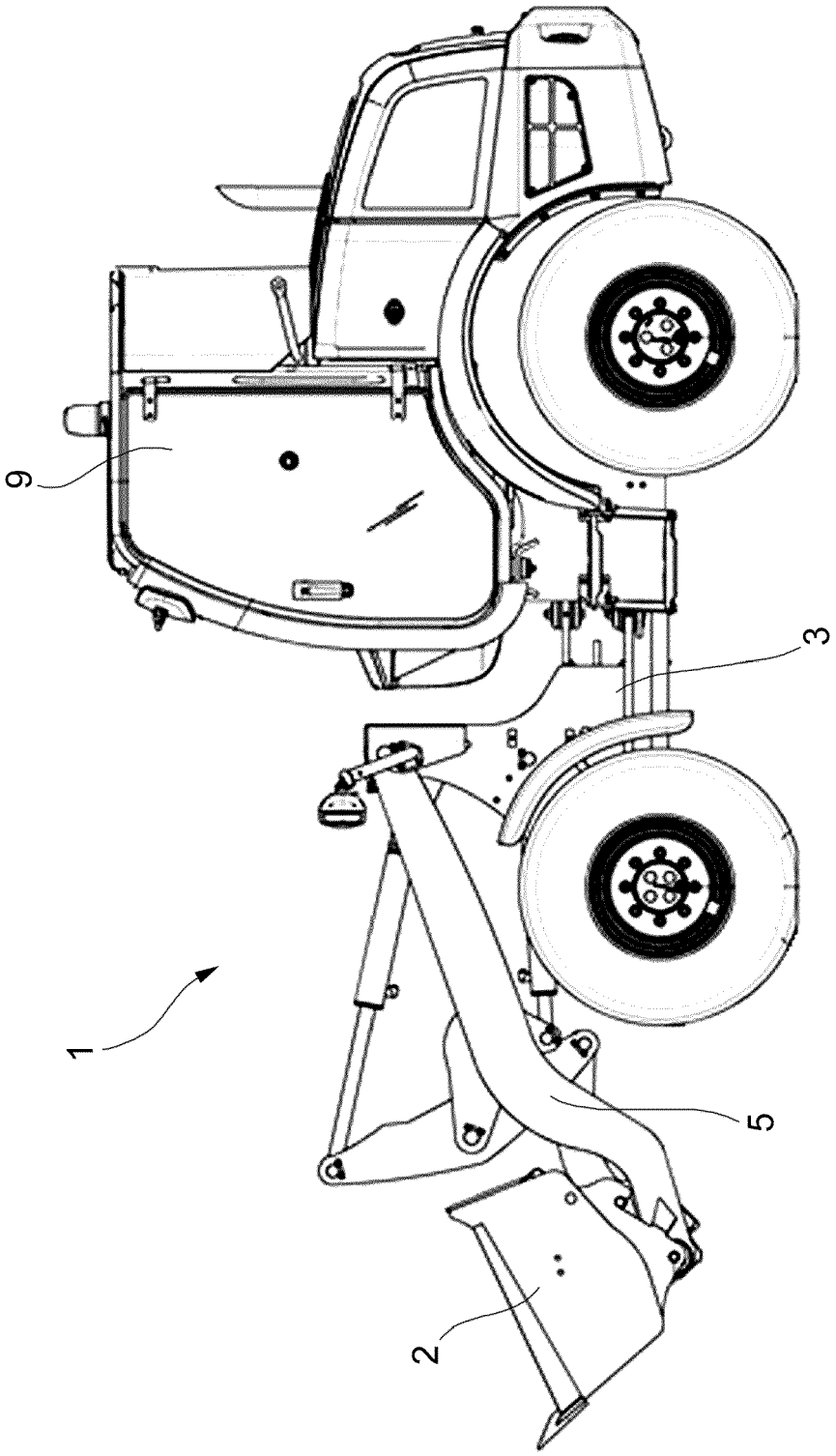

FIG.1
(PRIOR ART)

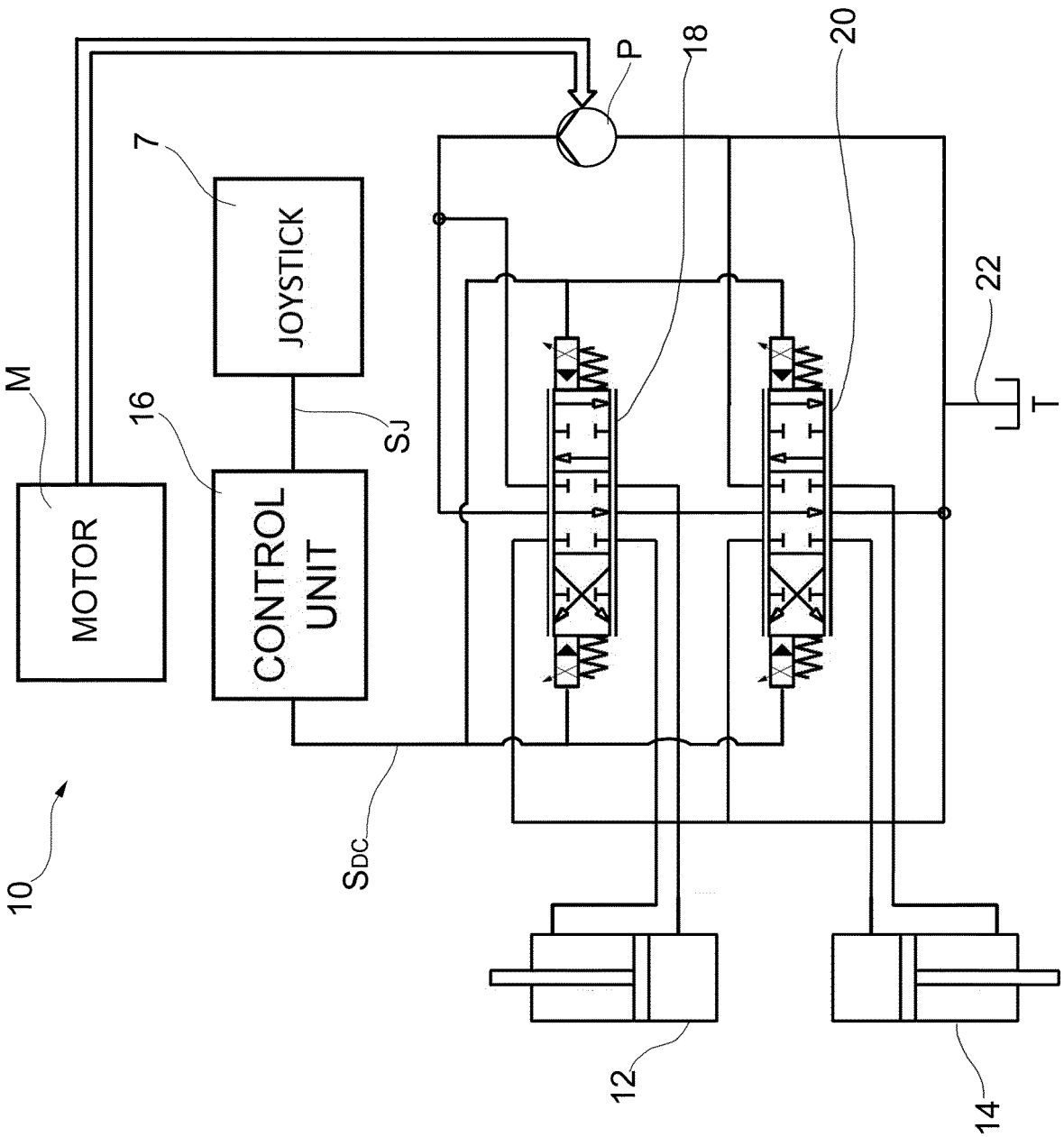

FIG.2
(PRIOR ART)

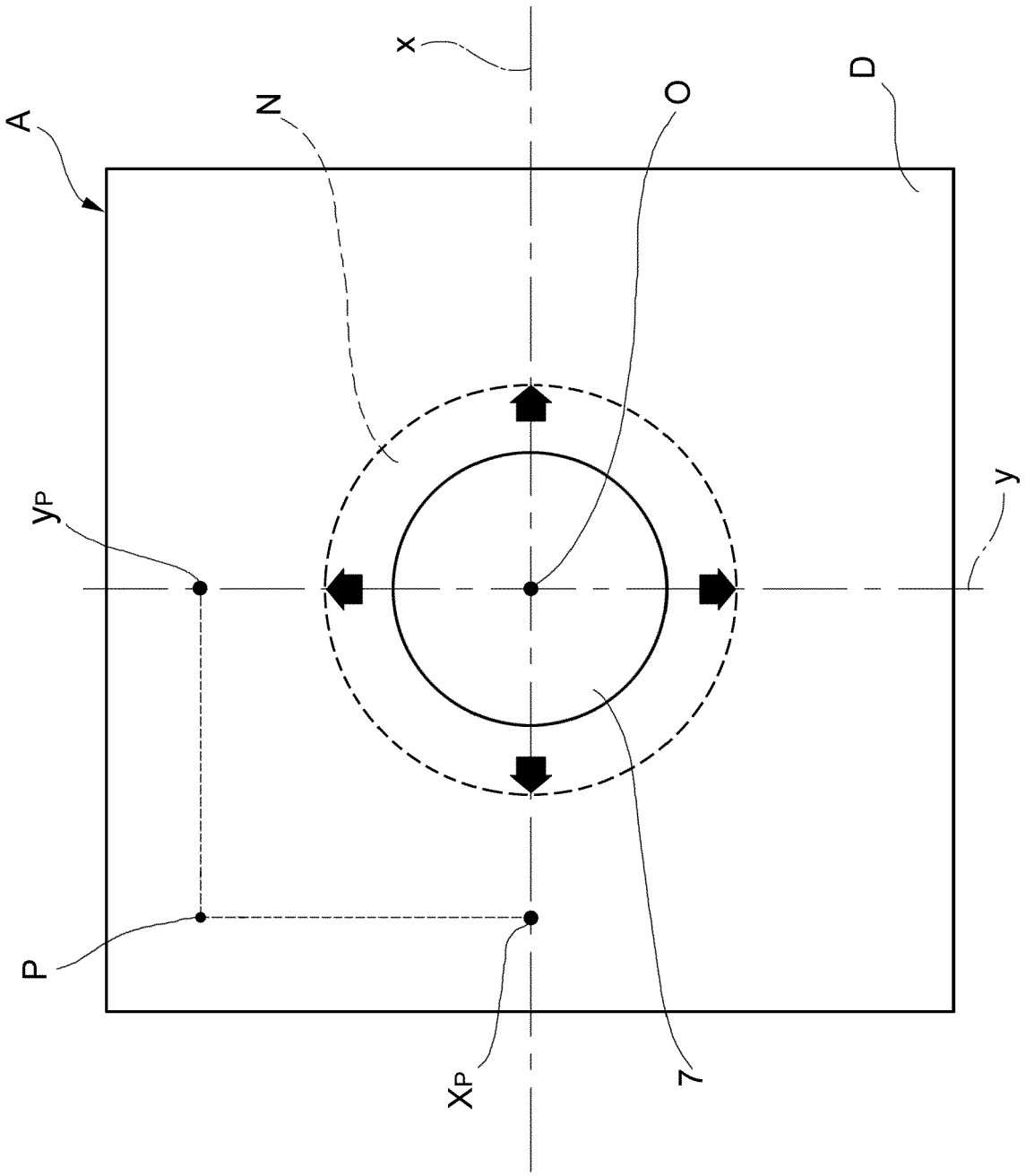

FIG.3
(PRIOR ART)

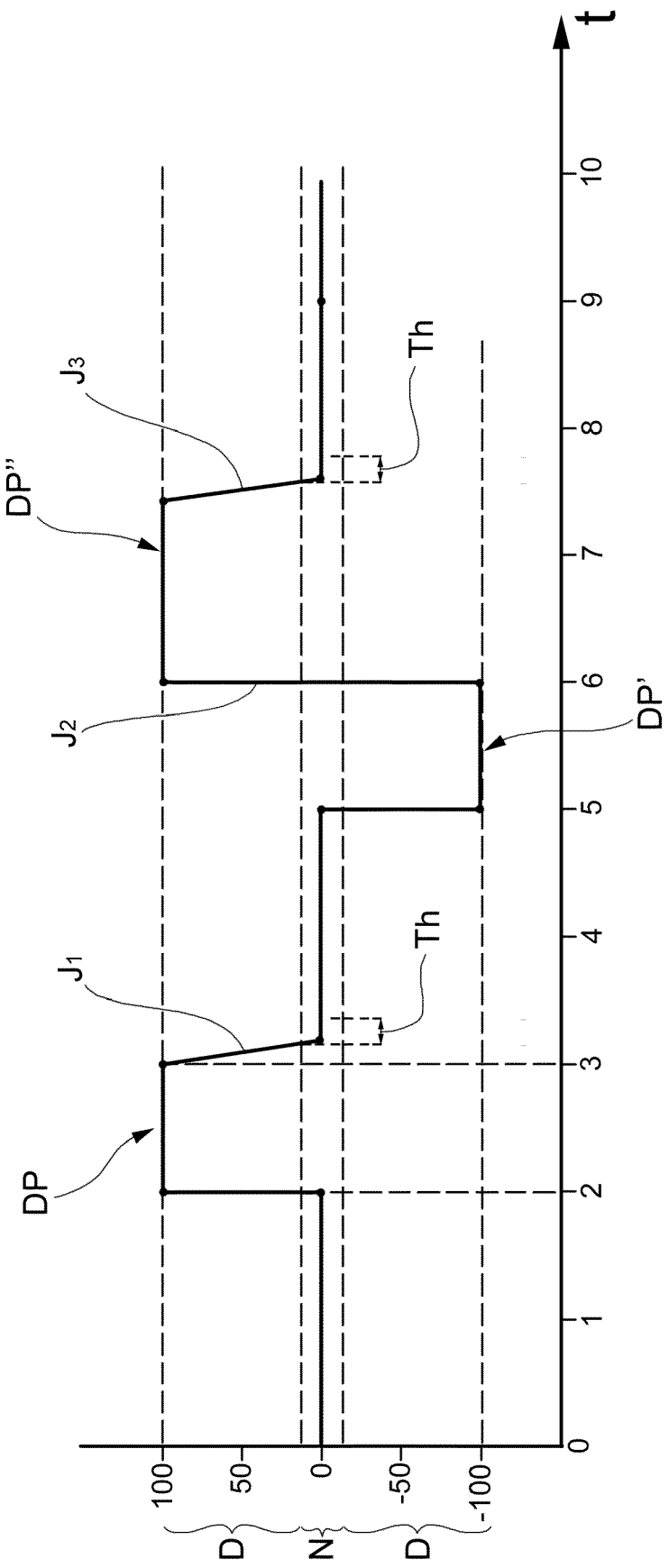

FIG.4

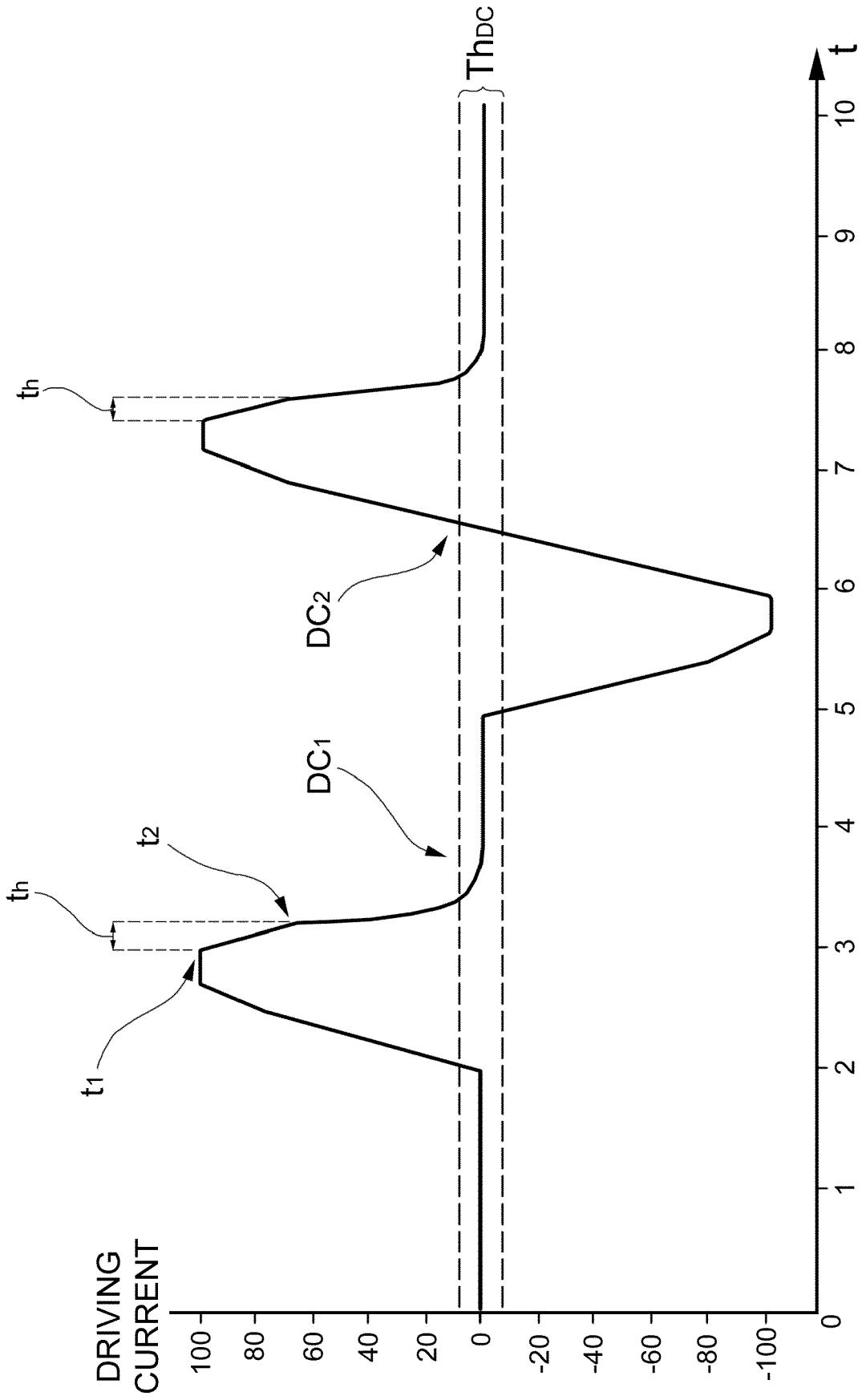
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FIG.5

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EUROPEAN SEARCH REPORT

Application Number
EP 20 16 8276

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)
E02F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	29 May 2020	Ferrien, Yann

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