(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 719 217 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.10.2020 Bulletin 2020/41

(51) Int Cl.:
E02F 9/20 *(2006.01)* ***E02F 9/22*** *(2006.01)*
E02F 3/43 *(2006.01)*

(21) Application number: **20168282.0**

(22) Date of filing: **06.04.2020**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **05.04.2019 IT 201900005248**

(71) Applicant: **CNH Industrial Italia S.p.A.**
10135 Torino (IT)

(72) Inventors:
- **Garramone, Adriano**
  73100 Lecce (IT)
- **Gravili, Andrea**
  CAP 73100 Lecce (IT)
- **Liberti, Stefano**
  73100 Lecce (IT)
- **Venezia, Antonio**
  10153 Torino (IT)

(74) Representative: **CNH Industrial IP Department**
Patent Department,
Leon Claeysstraat 3A
8210 Zedelgem (BE)

(54) A CONTROL METHOD FOR ACTUATING A RETURN-TO-DIG MOVEMENT OF AN IMPLEMENT, SUCH AS A BUCKET, IN A WORK VEHICLE, A CORRESPONDING CONTROL SYSTEM AND A WORK VEHICLE COMPRISING SUCH CONTROL SYSTEM

(57) A control method for actuating a return-to-dig movement of an implement in a work vehicle powered by a motor is disclosed. Actuating 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 preset direction causing the actuation of the implement by an hydraulic actuator. The hydraulic actuator includes an open centre directional solenoid valve whose opening degree is controlled by means of a driving current. The control method comprises determining that a return-to-dig manoeuvre is requested, acquiring a rotational speed of the motor, applying a modulated driving current of the open centre directional solenoid valve, based on a predetermined reference model, indicative of a nominal relation between the driving current of the open centre directional solenoid valve and the rotational speed of the motor, and setting the modulated driving current to zero when a predetermined reference tilt position of the implement is reached.

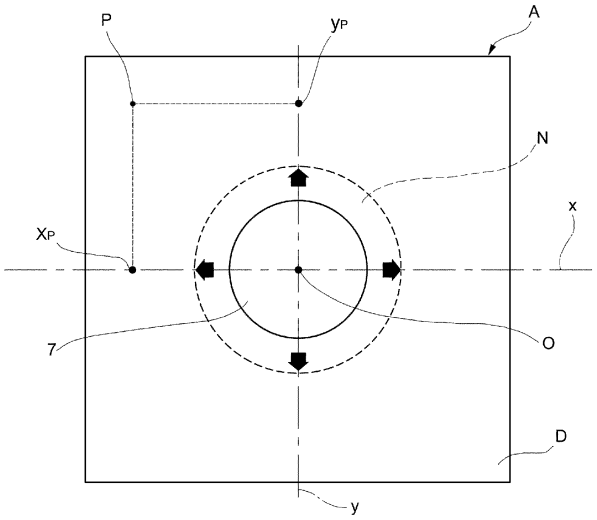

FIG.3
(PRIOR ART)

EP 3 719 217 A1

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 for actuating a return-to-dig movement of an implement, such as a bucket, 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 partial control diagram of the work vehicle 1, referred only to the control of bucket movement, the bucket 2 is moved by an hydraulic control circuit 10 comprising an hydraulic actuators 12 which is controlled by an electronic control unit 16 through a solenoid valve 18 according to the position of the joystick 7 controlled by the user.

[0008] The boom and further attachments that can be operated in parallel to the bucket by means of respective hydraulic actuators (not shown) which are controlled by the electronic control unit 16 through respective solenoid valves in a like manner, e.g. by means of push-buttons embodied in the joystick or according to the position of a separate joystick controlled by the user.

[0009] 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.

[0010] For example, the hydraulic actuator comprises an hydraulic cylinder operatively connected to the bucket, that uses hydraulic power of a working fluid to facilitate mechanical operation, the working fluid being controlled by means of an open centre directional solenoid valve 18. As liquids are nearly impossible to compress, a hydraulic actuator can exert a large force. The rate of actuation of the bucket is controlled by the opening degree of the open centre directional solenoid valve 18 by means of a driving current thereof as a function of the position of the joystick.

[0011] The hydraulic flow rate of the working fluid required to operate the bucket 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. The same motor is also used to drive the wheels as a propulsion means of the work vehicle. Therefore, the rate of movement of the bucket at a predetermined joystick position is dependent upon the motor rotational speed. For instance, when the motor is working at a high rotational speed, it is necessary a minimum movement of the joystick by the user to start the movement of the bucket. On the contrary, when the motor is working at a low rotational speed, or at idle, it is necessary a large movement of the joystick by the user to start the movement of the bucket.

[0012] 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 bi-dimensional control area A according to a second direction x causes the actuation of the bucket. 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.

[0013] A neutral region N around the neutral position of the joystick is a region where the boom and the bucket are not actuated. A region externally surrounding the neutral region is defined a driving region and indicated

D in this figure.

[0014] For example, according to the orientation depicted in figure 3, when the joystick is moved up from the origin O of the control area A according to the y direction the boom is lowered with respect to ground and when the joystick is moved down from the origin O according to the y direction the boom is lifted towards ground. Further, when the joystick is moved right from the origin O according to the x direction 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 bucket is tilted towards a rollback position.

[0015] 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.

[0016] Generally, after a dumping operation it is desirable that the bucket be returned to a dig position, where it is aligned flat with respect to ground. In standard loader type vehicles with open centre valve, separate control means are available to a user, such as for example a push-button, for automatically operating a return-to-dig actuation of the bucket. A proximity sensor switch is arranged to detect a bucket dig position, i.e. a bucket reference tilt position where it is horizontally aligned to ground or tilted at a predetermined threshold angle with respect to ground.

[0017] Disadvantageously, it is not possible to achieve the correct target tilt position at any motor rotational speed as this latter affects the hydraulic flow rate of the working fluid for operating the bucket hydraulic actuator, resulting in different tilting speed of the bucket when reaching the position detected by the proximity sensor. Different tilting speed of the bucket reaching the dig position cause a residual tilt of the bucket due to its inertia, and this residual tilt may vary, e.g. from 3° to 8° from the horizontal position, depending respectively upon a rotational speed of the motor.

[0018] In order to overcome the above drawback, it is known to provide a continuous position sensor, which is however an expensive solution.

Summary of the invention

[0019] 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 precision of a return-to-dig functionality, particularly for any rotational speed of the vehicle motor.

[0020] According to the invention, this aim is achieved by a control method for actuating a return-to-dig movement of an implement, such as a bucket, in a work vehicle, having the features claimed in claim 1.

[0021] 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.

[0022] Further subjects of the invention are a control system for actuating a return-to-dig movement of an implement, such as a bucket, in a work vehicle, as well as a work vehicle, as claimed.

[0023] In summary, an actuation strategy of an implement, such as a bucket, of a work vehicle in a return-to-dig actuation is disclosed according to which, based on information about a return-to-dig request by a user - that can be retrieved as an electronic signal provided by a push-button 8 associated with the joystick, the joystick position along the x direction - that can be retrieved as an electronic signal provided by a position sensor associated with the joystick, the achievement of a predetermined bucket reference tilt position where it is horizontally aligned to ground or tilted at a predetermined threshold angle with respect to ground - that can be retrieved as an electronic signal provided by a proximity sensor associated with the implement, and about the current rotational speed of the motor - that can be retrieved as an electronic signal provided on a CAN network of the vehicle, actuation is controlled by recognizing if the user is performing a return-to-dig manoeuvre of the implement and, in the affirmative, by modulating the driving current of the open centre directional solenoid valve of the hydraulic actuating means associated with the implement, depending on the motor rotational speed. Modulating the driving current comprises varying the amplitude of the driving current with an inverse proportionality relationship with the rotational speed of the motor as well as setting the driving current to zero when a predetermined bucket reference tilt position is reached.

Brief description of the drawings

[0024] 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 an exemplary prior art control diagram of a work vehicle;
- figure 3 shows a prior art exemplary joystick of a work vehicle; and
- figure 4 shows a control diagram of a work vehicle according to the invention.

Detailed description

[0025] 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.

[0026] In the following, a preferred embodiment of a control method for actuating a return-to-dig movement of an implement, such as a bucket , in a work vehicle is described. Reference is made to the control diagram of Figure 4, where the electronic control unit 16 is configured to implement the control method of the invention.

[0027] As disclosed above and with further reference to Figure 3, actuation of the implement 2 occurs by means of joystick 7 controlled by a user, whose movement in the control area A according to direction x causes the actuation of the implement 2 by hydraulic actuating means 12. A return-to-dig manoeuvre is be triggered by a push-button 14 associated with the joystick 7, if a return-to-dig enabling switch (not shown) is set to ON and the joystick is moved in the left direction along the x axis.

[0028] Hydraulic actuating means 12 include an hydraulic cylinder operatively connected respectively to the implement 2, and a respective open centre directional solenoid valve 18 whose opening degree is adapted to control the flow of a working fluid to the hydraulic cylinder.

[0029] The rate of actuation of the implement 2 is controlled by the opening degree of the open centre directional solenoid valve 18 by means of the driving current thereof, whose amplitude is generally a function of the position of the joystick 7 along direction x in the control area A. During a return-to-dig manoeuvre the rate of actuation of the rollback of the implement 2 is controlled by an opening degree of the open centre directional solenoid valve 18 set by means of a predetermined setpoint amplitude of the driving current and is dependent upon the rotational speed of the motor.

[0030] A proximity sensor 20 is coupled to the hydraulic actuating means 12 of the implement, and a proximity switch 22 is connected to the proximity sensor and configured to switch a binary proximity signal S_P from a first value indicative of the fact that the current bucket tilt is different from a predetermined bucket reference tilt position where the bucket is tilted at a predetermined threshold angle with respect to ground, i.e. the bucket is remote from a bucket dig position, and a second value indicative of the fact that the current bucket tilt corresponds to the predetermined bucket reference tilt position where the bucket is tilted at a predetermined threshold angle with respect to ground, i.e. the bucket is proximate to the bucket dig position. When the bucket tilt is remote from a bucket dig position, the actuation of the bucket is enabled, whereas when the bucket tilt is proximate to the bucket dig position the actuation of the bucket is stopped.

[0031] The electronic control unit 16 has first input means adapted to receive a signal S_J indicative of a position of the joystick along the x axis in the control area, second input means adapted to receive a signal S_R indicative of a return-to-dig request or command, third input means adapted to receive a signal S_E indicative of the rotational speed of the motor M, and fourth input means adapted to receive the proximity signal S_P, as well s output means adapted to issue at least a signal S_{DC} indicative of the driving current intended to control an opening degree of the open centre directional solenoid valve 18.

[0032] The electronic control unit has also memory means (not shown) storing a predetermined reference model of a modulated driving current of the open centre directional solenoid valve 18, indicative of a nominal relation between the driving current and the rotational speed of the motor. Specifically, said reference model is an analytical relationship between, or a map of numerical values in a bijective correspondence of, the driving current and the rotational speed of the motor - corresponding to the actuation command of the implement when Return to dig function is activated by operator as previously described.

[0033] In operation, the electronic control unit 16 is configured to acquire the signal S_J indicative of the position of the joystick 7 in the control area A, particularly the component of the position of the joystick along the x axis. The electronic control unit is also configured to acquire the signal S_E indicative of the rotational speed of the motor M.

[0034] When a return-to-dig functionality is enabled, i. e. a return-to-dig enabling switch (not shown) is set to ON, the electronic control unit is able to detect a return-to-dig operation by receiving the signal S_J indicative of a joystick position corresponding to an implement rollback actuation and the signal S_R indicative of a return-to-dig request or command.

[0035] When the electronic control unit determines that a return-to-dig operation is requested the electronic control unit applies a modulated driving current to the open centre directional solenoid valve 18 of the implement according to the stored predetermined reference model, based on the current rotational speed of the motor acquired through the signal S_E, by means of the signal S_{DC}.

[0036] The modulated driving current is applied as long as the proximity signal S_P has a first value indicative that the current bucket tilt is different from the predetermined bucket reference tilt position, i.e. the bucket is remote from a bucket dig position. When the electronic control unit 16 detects that the proximity signal S_P has a second value indicative that the current bucket tilt corresponds to the predetermined bucket reference tilt position, i.e. the bucket is proximate to the bucket dig position, the electronic control unit 16 sets the modulated driving current to zero.

[0037] Advantageously, the predetermined bucket reference tilt position detected by the proximity sensor is set at a reference rotational speed of the motor, such as for example a reference minimum rotational speed of the motor (idle) and a predetermined return-to-dig nominal driving current of the open centre solenoid valve 18, corresponding to a predetermined hydraulic flow rate of the working fluid, whereby the bucket dig position horizontal to ground is reached due to known hydraulic actuation delay and the inertia of the bucket. Consequently, the reference model is calculated as a modulation of the driv-

ing current so as to maintain the hydraulic flow rate of the working fluid constant when the rotational speed of the motor varies.

[0038] 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.

[0039] Therefore, by virtue of the present invention, the opening degree of the open centre directional solenoid valve of the hydraulic actuating means associated with the implement is modulated depending on the motor rotational speed so as to mitigate effect of said speed in a return-to-dig manoeuvre for actuating the implement, such as a bucket, to a bucket dig position where it is horizontally aligned to ground .

[0040] 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.

[0041] 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 return-to-dig movement of an implement in a work vehicle powered by a motor,
   wherein actuating 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 preset direction causing the actuation of the implement by hydraulic actuating means,
   wherein the hydraulic actuating means include an hydraulic cylinder operatively connected to the implement, and an open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid to the hydraulic cylinder,
   the rate of actuation of the implement being controlled by the opening degree of the open centre directional solenoid valve by means of a driving current thereof,
   the control method comprising the steps of:

   a) determining whether a return-to-dig manoeuvre is requested;
   b) acquiring a signal or data indicative of a current rotational speed of the motor;
   c) when a return-to-dig manoeuvre is requested, applying a modulated driving current of the open centre directional solenoid valve, based on a predetermined reference model, indicative of a nominal relation between the driving current of the open centre directional solenoid valve, and the rotational speed of the motor; and
   d) setting the modulated driving current to zero when a predetermined reference tilt position of the implement is reached.

2. The control method according to claim 1, wherein said predetermined reference model is an analytical relationship between, or a map of numerical values in a bijective correspondence of, the driving current of the open centre directional solenoid valve and the rotational speed of the motor.

3. The control method according to claim 1 or 2, wherein said reference tilt position of the implement is a position where the implement is horizontally aligned to ground or tilted at a predetermined threshold angle with respect to ground.

4. The control method according to any one of the preceding claims, wherein determining that a return-to-dig manoeuvre is requested includes detecting that a return-to-dig push-button associated with the joystick is operated and detecting a predetermined joystick position in said preset direction.

5. The control method according to claim 4, wherein said predetermined joystick position in said preset direction is a position of the joystick indicative of a rollback actuation of the implement.

6. The control method according to any one of the preceding claims, wherein the predetermined reference tilt position of the implement is set at a reference rotational speed of the motor and a predetermined nominal driving current of the open centre solenoid valve, and the reference model is calculated to provide a modulated driving current as a function of the rotational speed of the motor so as to have a predetermined hydraulic flow rate of the working fluid to the hydraulic actuating means of the implement correspond to the hydraulic flow rate that would be achieved at the reference rotational speed of the motor and the predetermined nominal driving current.

7. A control system for actuating a return-to-dig movement of an implement in a work vehicle powered by a motor, comprising:

   - first input means adapted to receive a return-to-dig manoeuvre request;
   - second input means adapted to receive a sig-

nal indicative of the rotational speed of the motor;
- third input means adapted to receive a signal correlated to the current tilt position of the implement;
- output means adapted to issue a signal indicative of a modulated driving current intended to control an opening degree of the open centre directional solenoid valve of the hydraulic actuating means of said implement; and
- memory means adapted to store a predetermined reference model of a modulated driving current, indicative of a nominal relation between the driving current of the open centre directional solenoid valve, and the rotational speed of the motor;

the system being arranged to carry out a control method according to any one of claims 1 to 6.

8. Work vehicle, in particular compact wheel loader, comprising:

- a motor for propulsion of the work vehicle;
- an implement;
- a joystick operatively controlled by a user for actuating the implement, the joystick being movable in a predetermined control area according to a preset direction for actuating the implement;
- hydraulic actuating means for actuating the implement, including an hydraulic cylinder operatively connected to the implement, and a open centre directional solenoid valve whose opening degree is adapted to control the flow of a working fluid supplied by pumping means to the hydraulic cylinder, the pumping means being driven by the motor of the work vehicle,

wherein the opening degree of said open centre directional solenoid valve is operatively controlled by means of a driving current thereof; and

- a control system for actuating a return-to-dig movement of the implement, according to claim 7.

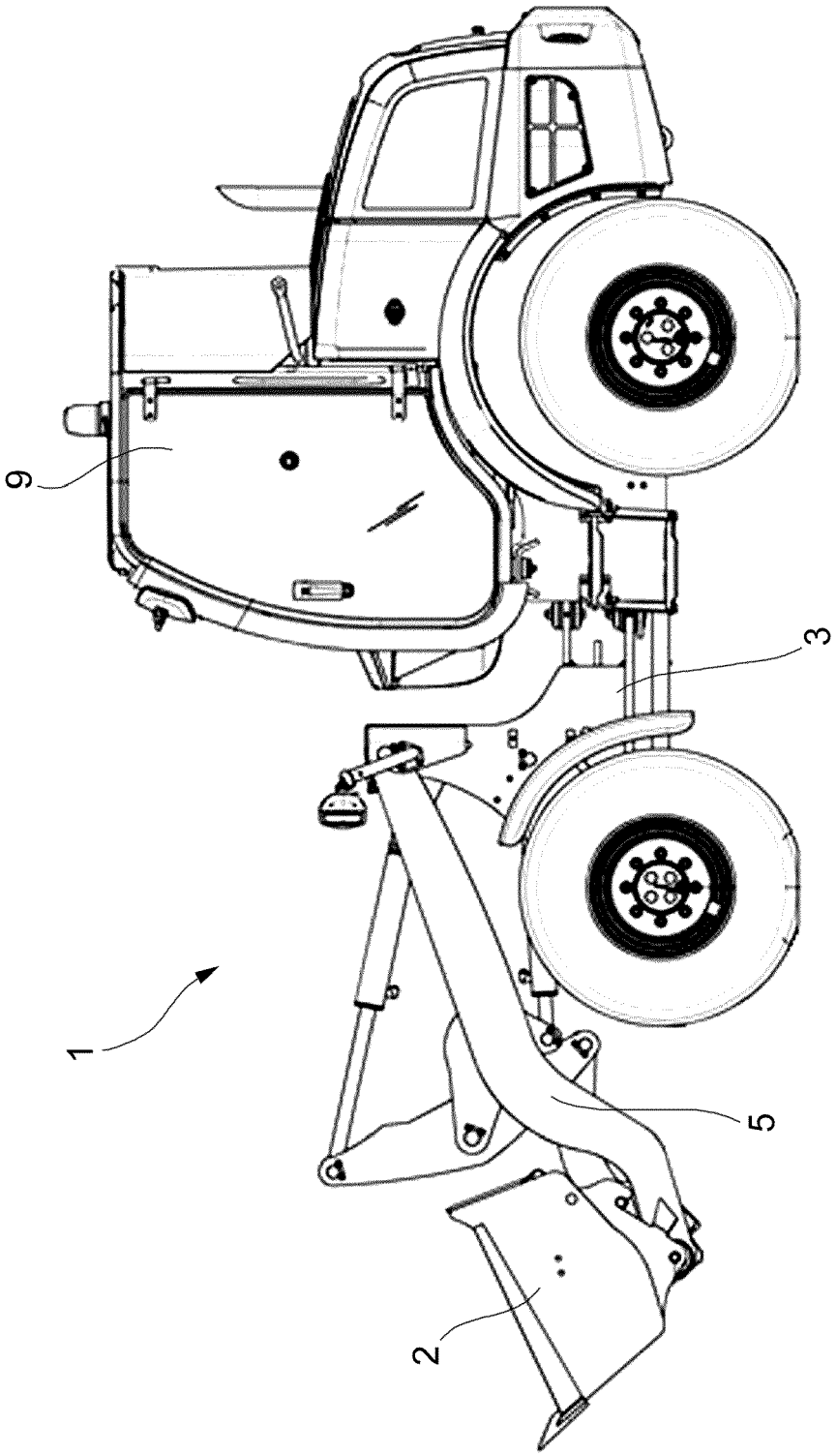

FIG.1
(PRIOR ART)

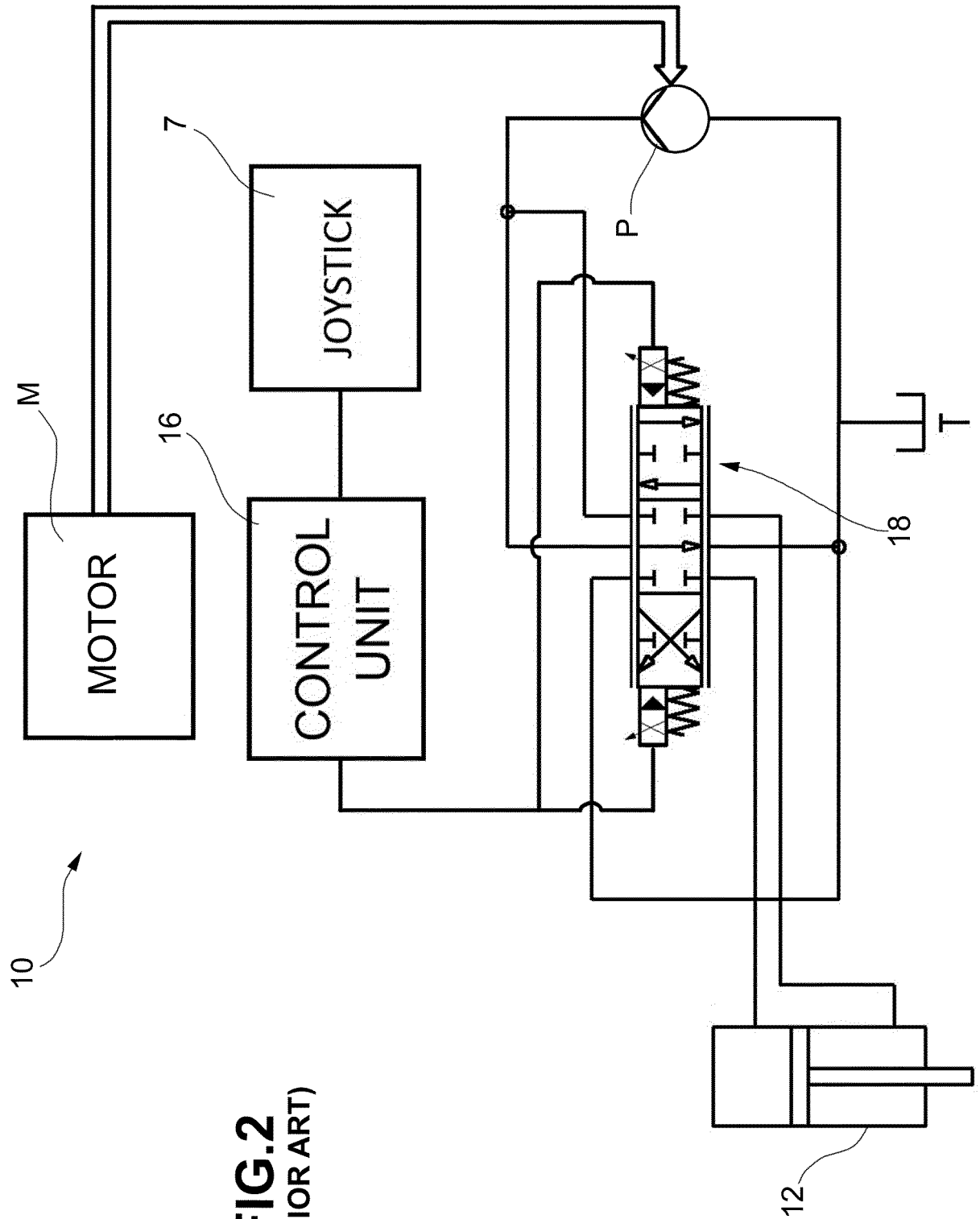

FIG.2
(PRIOR ART)

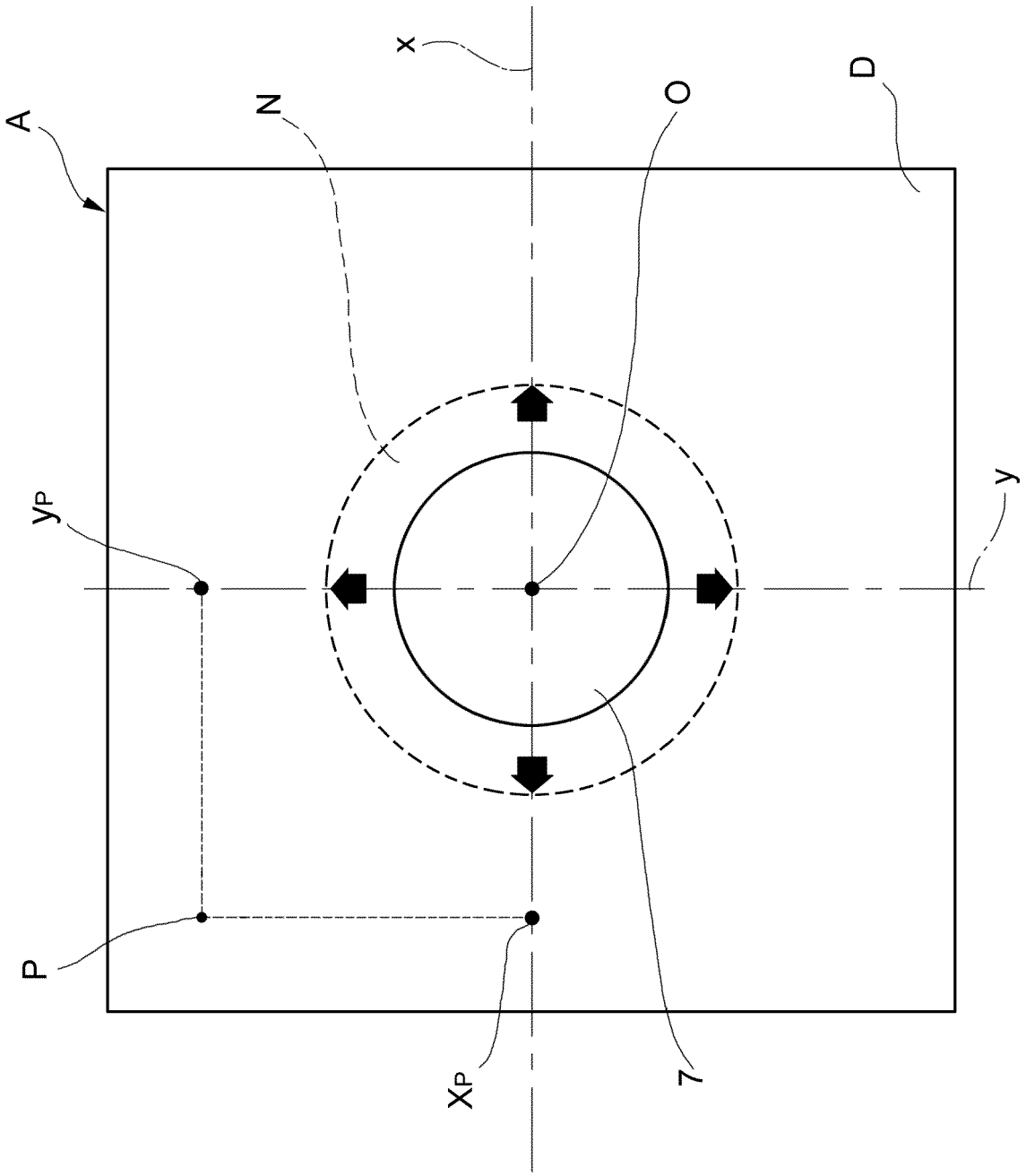

FIG.3
(PRIOR ART)

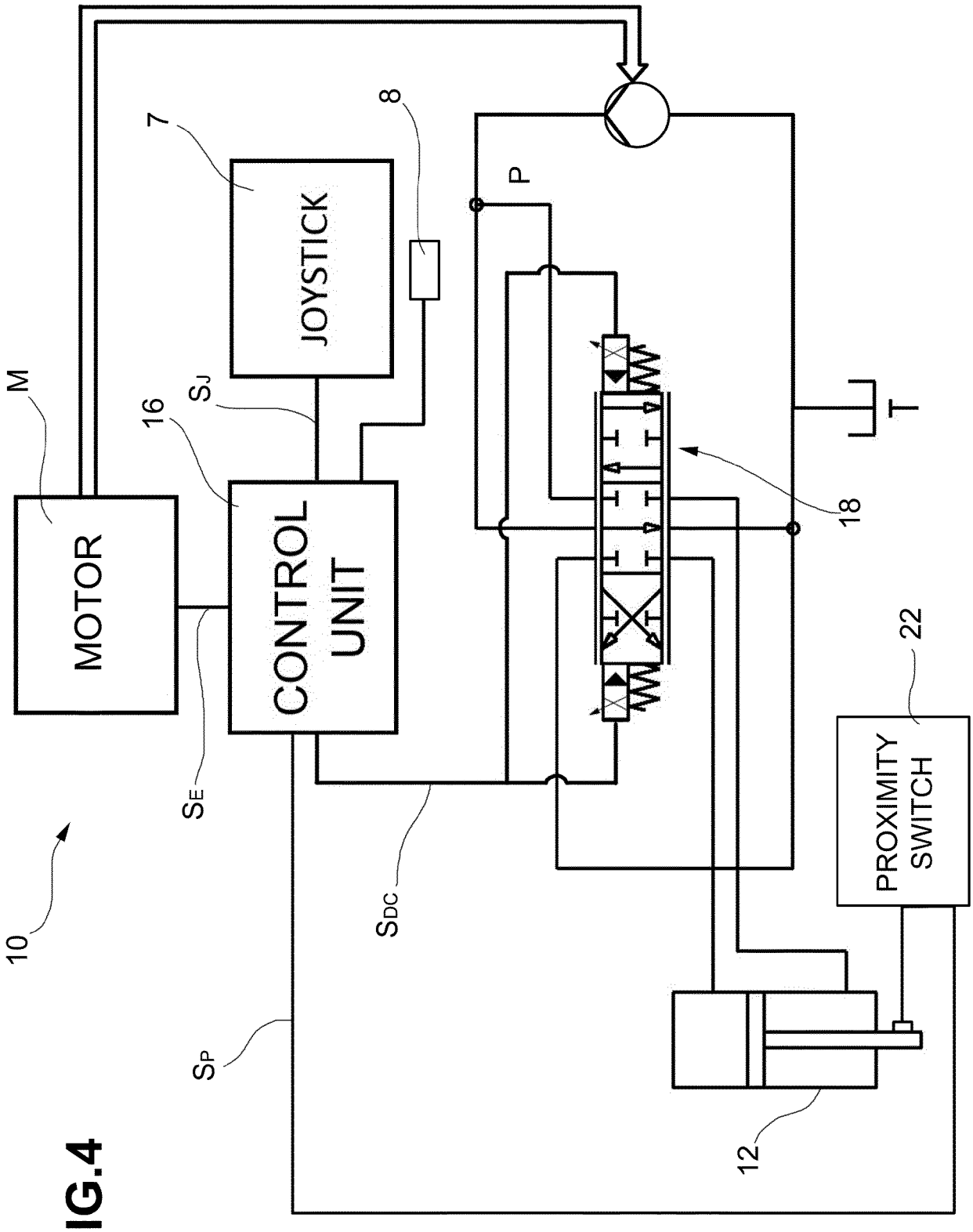
M
MOTOR
16
CONTROL UNIT
7
JOYSTICK
8
S_J
S_E
S_{DC}
S_P
10
P
T
18
22
PROXIMITY SWITCH
12

FIG.4

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 20 16 8282

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	US 2008/313935 A1 (TRIFUNOVIC BORIS [US]) 25 December 2008 (2008-12-25) * paragraphs [0057] - [0060]; figures 8,11 * * paragraph [0033]; figures 1-3 * * abstract *	1-8	INV. E02F9/20 E02F9/22 E02F3/43
A	US 2011/150614 A1 (NICHOLSON CHRISTIAN [US] ET AL) 23 June 2011 (2011-06-23) * paragraph [0027]; figure 3 * * abstract; figures 1-2 *	1-8	
A	WO 2012/053197 A1 (HITACHI CONSTRUCTION MACHINERY [JP]; DOI SHINTARO [JP]) 26 April 2012 (2012-04-26) * abstract; figures 1,2 *	1-8	

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

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 20 16 8282

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

29-05-2020

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008313935 A1	25-12-2008	NONE	
US 2011150614 A1	23-06-2011	US 2011150614 A1	23-06-2011
		WO 2012108923 A1	16-08-2012
WO 2012053197 A1	26-04-2012	JP 2012087541 A	10-05-2012
		WO 2012053197 A1	26-04-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82