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(54) **ELECTRO-HYDRAULIC ACTUATION CIRCUIT OF A HYDRAULIC ACTUATOR FOR AN ELECTRIFIED WORK VEHICLE AND CORRESPONDING METHOD**

(57) An electro-hydraulic circuit includes a fixed displacement hydraulic pump (P) and an electric motor (M) arranged to drive the hydraulic pump in rotation, a recovery tank (T), a hydraulic actuator (BOOM, BUCKET), an open center proportional directional electro-valve (V1, V2) comprising a release condition in which it isolates the hydraulic actuator by hydraulically connecting the hydraulic pump with the recovery tank, a selector (SEL) to select a mode of execution of a repetitive operation of the actuator, a processing unit (STK) to receive the signals of the selector and an input device (Joystick) operated by a user and generate control signals for the electro-valve (V2) and for the engine (M), wherein a number of revolutions of the electric motor (M) is determined based on the selector and an amplitude of oscillation of the input device as it is manipulated by the user to perform the repetitive operation, and a frequency of the command signal for the electro-valve (V2) it is determined on the basis of a frequency acquired through the input device.

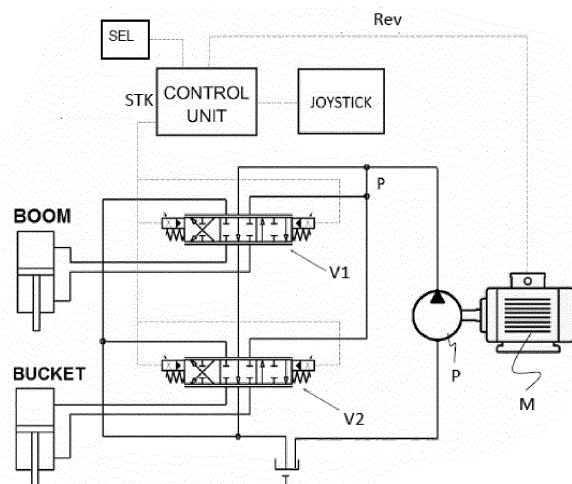


Fig. 1

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Description

Field of the invention

[0001] The present invention relates to the field of work vehicles, including electrified agricultural vehicles, and in particular of the type comprising an electro-hydraulic circuit for actuating at least one hydraulic member, including an arm and/or a bucket.

State of the art

[0002] In the field of work and agricultural vehicles, the operation of users, such as arms and related tools, is carried out by means of a hydraulic circuit.

[0003] The hydraulic circuit is powered by a hydraulic pump driven in rotation by a prime mover, very often an internal combustion engine.

[0004] The need is also felt to provide the user of the work or agricultural vehicle with an aid for the management of repetitive operations, such as shaking the tool e.g. a shovel, to remove debris such as sand, mud etc. through inertial effects. In this way, the user's attention is focused on the execution of main and complex operations such as the operation on the working site or in the tool field.

[0005] The progressive technological development of battery power systems makes it possible to design work vehicles with electric traction and/or with hydraulic systems operated by electric motors, such as a hydraulic circuit for the actuation of at least one hydraulic actuator enslaved to the movement of a hydraulic work member.

[0006] By "work hydraulic unit" it is meant one of those components distinct and separate from those inherent to the movement of the work vehicle, such as for example transmissions, braking systems, etc. Hereinafter, for convenience, reference is made to a "hydraulic member" meaning a "working hydraulic member". The electrification of a work vehicle involves the elimination of the internal combustion engine in favour of at least one electric motor.

[0007] For example, it is possible to provide a first electric motor used exclusively to drive the hydraulic pump for feeding at least one hydraulic working member in rotation. A second electric motor can be provided for moving the vehicle.

[0008] There are many differences between internal combustion engines and electric motors. In addition to the substantial different source of energy, the internal combustion engine, when active, has a minimum rotation speed, which is essential for its operation, while an electric motor starts rotation as soon as it is electrically powered.

[0009] All of this has repercussions on the operation of the hydraulic pump driven by the first electric motor.

[0010] A minimum rotation speed of the electric motor implies a consumption of electricity not necessary for the intrinsic operation of the same.

[0011] Saving electricity is essential to allow the diffusion of electrified vehicles, replacing traditional work vehicles equipped with internal combustion engines.

[0012] If not specifically excluded in the detailed description that follows, what is described in this chapter is to be considered as an integral part of the detailed description.

Summary of the invention

[0013] The purpose of the present invention is to propose a method and system for saving electricity in an electrified work vehicle and, at the same time, to provide aids to the user, in particular for the execution of secondary, simple and functional functions, in order to reduce the probability of breakdowns during the useful life of the work or agricultural vehicle. In particular, for those work vehicles completely without an internal combustion engine.

[0014] The object of the present invention is to provide a hydraulic circuit for moving a hydraulic working member comprising a fixed displacement hydraulic pump and an open center control directional electro-valve controlled by the user by means of a joystick, wherein the electro-valve and the motor are controlled to assist the user in performing the secondary function of shaking the hydraulic work member to remove unwanted debris.

[0015] The basic idea is to provide, in the hydraulic circuit indicated above:

- a selector for the shaking execution mode; the selector can be either analogic like a knob, a lever or a push-button panel, or digital, like a touch screen programmed to display the execution modes;
- a module for measuring the frequency and amplitude of the signal of the input device to detect the frequency and amplitude with which a user applies an oscillatory movement on the input device (e.g. joystick);
- a command module:
 - to generate a signal for the electric motor and to set a number of revolutions based on the amplitude of the signal from the input device and the mode identified by the selector; and
 - to generate a command signal frequency for the electro-valve (V2) determined on the basis of a frequency acquired through the input device while being manipulated by a user to perform the repetitive operation.

[0016] Preferably, an oscillatory signal is also generated for the control electro-valve having an amplitude based on the amplitude of the input device signal and the mode identified by the selector.

[0017] In this way, the flow rate variation is operated through the motor control and this allows only the flow of oil necessary for the shaking operation to be sent to the hydraulic member, avoiding the dissipations resulting

from the discharging of the oil flow towards the tank.

[0018] According to one embodiment:

- the module for measuring the frequency and amplitude of the signal of the input device is configured to continuously detect the frequency and amplitude during operation of the hydraulic work member
- the command module activates the shaking function when the detected frequency is greater than or equal to a predefined threshold and deactivates it when the detected frequency is lower than the aforesaid predefined threshold.

[0019] According to one embodiment, the module for measuring the frequency and amplitude of the signal of the input device is configured to detect the frequency and amplitude of a movement of the joystick along a predefined axis.

[0020] The dependent claims describe preferred variants of the invention, forming an integral part of this description.

Brief description of the figures

[0021] Further objects and advantages of the present invention will become clear from the following detailed description of an example of embodiment of the same (and its variants) and from the attached drawings given purely for explanatory and non-limiting purposes, in which:

Figure 1 shows an example of an electro-hydraulic circuit according to the present invention;

Figure 2 shows a work vehicle implementing the present invention; And

Figure 3 shows superimposed diagrams of input and output signals of a processing unit of the electro-hydraulic circuit of the invention.

Figure 4 shows an example of two maps respectively with the amplitude values of the bucket command signal and with the motor rotation speed values for three thresholds of the shaking mode, as a function of three intervals of amplitudes for the joystick input.

[0022] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0023] It should also be noted that the terms "first", "second", "third", "upper", "lower" and the like can be used as labels 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.

[0024] 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

[0025] Figure 1 shows an example of an electro-hydraulic circuit comprising hydraulic actuators of hydraulic working members and are indicated with "BOOM" and BUCKET ", that are labels taken from the Anglo-Saxon terminology that indicates an arm "Boom" of a work or agricultural vehicle and a relative bucket "Bucket". The electro-hydraulic circuit also includes a fixed displacement pump P and an electric motor M.

[0026] Figure 1 shows two proportional directional control electrovalves with open center V1 and V2 which have a corresponding center closed towards the actuator and open towards the pump P in the release position to connect the latter to the storage tank. In addition, the valve V2 relating to the bucket is controlled to simplify a shaking operation that an operator performs via a manual control device, e.g. a joystick, swinging with respect to a neutral position along an axis e.g. an X axis of the joystick representative of the angular movement of the bucket in one direction and in the opposite one. The electro-hydraulic circuit also includes a processing unit STK configured to receive the electrical signals from the joystick and generate the electrical control signals for the valves V1, V2 and the electrical control signal REV for the motor M.

[0027] Figure 2 shows a work vehicle WL, a mechanical shovel, with an arm B with the hydraulic actuator A1 corresponding to the label "BOOM" in figure 1 and a shovel or bucket SH with the relative actuator A2 corresponding to the label "BUCKET" of figure 1.

[0028] The vehicle WL is equipped with a battery pack BAT and an electric motor M with at least one hydraulic circuit similar to the one of figure 1, connected to a relative frame F. Each of the illustrated actuators is of the double-acting type, i.e. it has two opposing chambers which serve for example to raise and lower an arm. Each chamber includes a port through which the hydraulic oil is forced to enter or exit. Hydraulic oil is forced out of the port of a first chamber when hydraulic oil is pumped into the second chamber, opposite the first, of the same actuator.

[0029] The directional electro-valve is configured to keep the port of both opposing chambers closed when the joystick is in the release position, in order to keep said hydraulic member still. In these conditions, the movable spool is in a central position in the valve body, inhibiting the passage of oil towards both chambers of the actuator and directing all the oil to the collection tank T.

[0030] Each valve is represented with three spools, in a per se known manner. Remembering that it is a proportional valve, that is able to reach intermediate positions between the position of complete closure and complete opening towards one or the other actuator chamber.

[0031] In greater detail, a manual selector SEL is connected to the processing unit, for example a knob located in the passenger compartment, so that the user can select a shaking mode, for example identified in at least two thresholds: a softer one and a one more abrupt, or pref-

erably three: one softer (LOW), one intermediate (MEDIUM) and another abrupt (HIGH).

[0032] When the shaking is activated, the processing unit:

- generates predefined oscillatory electric signal for commanding the electro-valve V2 (i.e. of the bucket) depending on the frequency and, preferably, on the joystick oscillation amplitude and on the mode selected using the selector SEL;
- in combination or alternative with the dependence on the amplitude of oscillation, it controls a predefined number of revolutions of the electric motor, depending on the amplitude of oscillation of the Joystick and/or on the mode selected using the selector SEL.

[0033] The processing unit is programmed according to known algorithms to detect an oscillation frequency of the Joystick along its own axis, for example the X axis corresponding to the movement of the bucket, and an amplitude of this oscillation. In both cases, the user manually operates the joystick to apply the aforementioned inputs. According to a preferred embodiment, the frequency is an average frequency calculated as the number of reaching of the neutral position in the unit of time.

[0034] The amplitude of the bucket command signal is generated at discrete thresholds through the range of joystick oscillation amplitudes; i.e. a first predefined value of the signal amplitude is common to a first interval of detected Joystick oscillation amplitudes, a second predefined value greater than the first value is common to a second interval of amplitudes greater than those of the first interval etc., so to favour the stability of the movement of the bucket.

[0035] Furthermore, preferably, the number of revolutions of the motor M is controlled at discrete thresholds through the range of oscillation amplitudes of the Joystick; i.e. a first predefined value of the number of revolutions of the motor is common to a first interval of amplitudes of the signal amplitudes of the Joystick oscillation detected, a second predefined value greater than the first value is common to a second interval of amplitudes greater than those of the first interval, etc..

[0036] Therefore, in the case of three amplitude ranges for the joystick input and three thresholds of shaking mode, the processing unit stores a map of 9 motor rotation speed values and 9 amplitude values of the control signal of the bucket (see figure 4).

[0037] Furthermore, preferably, the frequency of the bucket control signal has the same oscillation frequency as the Joystick.

[0038] According to the combined effect of the engine speed map and the bucket control signal amplitude map as a function of the amplitude input signals generated by the joystick, when the high threshold is selected the valve V2 with the same operation by the user, opens more and receives a greater flow rate and this makes the shaking

of the bucket more energetic than selecting the soft mode (LOW), defined, always with the same input signals, by a lower flow rate and valve opening.

[0039] Figure 3 shows the parameters mentioned above according to an example of construction referred to the selection of the most abrupt mode of shaking (HIGH) by means of the selector SEL:

- The three sinusoids refer to corresponding signals generated by the joystick (Joystick position) having the same frequency and three different amplitudes. Each amplitude is within a pre-defined and programmable range, respectively low range joystick, medium range joystick and high range joystick;
- Motor_LH, Motor_MH, Motor_HH correspond respectively to the pre-determined and programmable numbers of revolutions (Motor rpm) corresponding to the three amplitude intervals detected by processing the sinusoidal signal output from the Joystick;
- The three square-waves Bucket CMD_LH, Bucket CMD_MH, Bucket CMD_HH correspond respectively to the control signals of the valve V2 generated by the processing unit STK, have the same frequency as the sine waves of the joystick, and are pre-determined and programmable corresponding to the three amplitude intervals detected by processing the sinusoidal signal output from the Joystick.

[0040] 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.

[0041] 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. Electro-hydraulic circuit comprising

- a fixed displacement hydraulic pump (P) and an electric motor (M) arranged to drive the hydraulic pump in rotation,
- a recovery tank (T) arranged to collect hydraulic oil,
- a hydraulic actuator (BOOM, BUCKET) arranged to move a work member (B) and to be supplied by the hydraulic circuit,
- an open center proportional directional electro-valve (V1, V2) operatively interposed between said fixed displacement hydraulic pump and said actuator and comprising a release condition in which it isolates the hydraulic actuator by hydraulically connecting the hydraulic pump with the recovery tank (T),
- a selector (SEL) to select a mode of execution

of a repetitive operation of the actuator

- a processing unit (STK) to receive the signals of the selector and of an input device (Joystick) arranged to be operated by a user and to generate command signals for the electro-valve (V2) and for the motor (M),
wherein
- A number of revolutions of the electric motor (M) is determined on the basis of the selector and an amplitude of oscillation of the input device while it is manipulated by the user to perform the repetitive operation, and

A command signal frequency for the electro-valve (V2) is determined on the basis of a frequency acquired through the input device while it is manipulated by the user to perform the repetitive operation.

2. Circuit according to claim 1, wherein the amplitude of the command signal for the electro-valve (V2) is determined based on the selector and the amplitude of oscillation of the input device while manipulated by the user to perform the repetitive operation.

3. Circuit according to the previous claim 1, wherein the frequency is detected by oscillatory movements of the input device with respect to a neutral position of the device itself.

4. Method of controlling a work vehicle comprising:

- a fixed displacement hydraulic pump (P) and an electric motor (M) arranged to drive the hydraulic pump in rotation,
- a recovery tank (T) arranged to collect hydraulic oil,
- a hydraulic actuator (BOOM, BUCKET) arranged to move a work member (B, T) and to be supplied by the hydraulic circuit,
- an open center proportional directional electro-valve (V1, V2) operatively interposed between said fixed displacement hydraulic pump and said actuator and comprising a release condition in which it isolates the hydraulic actuator by hydraulically connecting the hydraulic pump with the tank recovery,
- a selector (SEL) to select a mode of execution of a repetitive operation of the actuator,
- a processing unit (STK) to receive the signals of the selector and an input device (Joystick) arranged to be operated by a user and to generate command signals for the electro-valve (V2) and for the motor (M),

Comprising the following steps:

- Determining a number of revolutions of the electric motor (M) on the basis of the selector

and an amplitude of oscillation of the input device while it is manipulated by a user to perform the repetitive operation; And

- Determining a command signal frequency for the electro-valve (V2) is determined on the basis of a frequency acquired through the input device while being manipulated by a user to perform the repetitive operation.

5. The method according to claim 4, further comprising the step of determining an amplitude of the command signal for the electro-valve (V2) based on the selector and an amplitude of oscillation of the input device while being manipulated by the user to perform the repetitive operation.

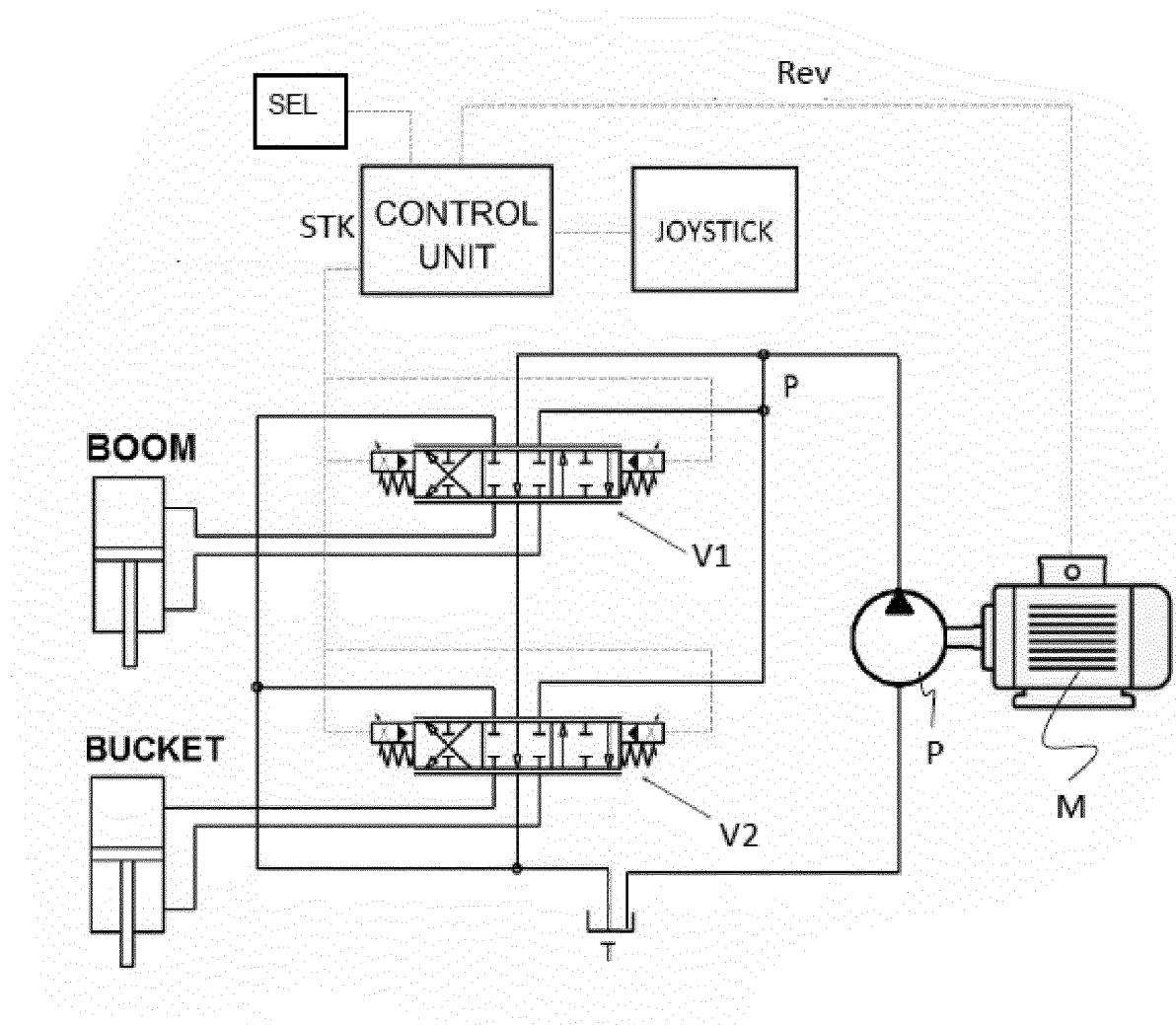


Fig. 1

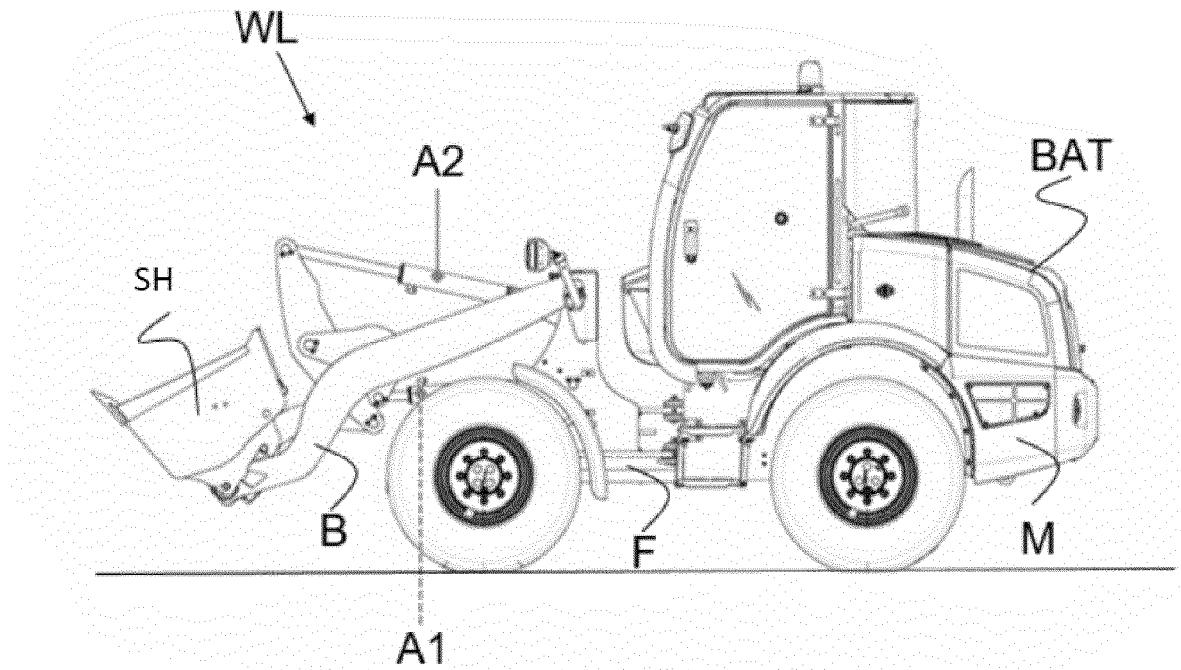


Fig. 2

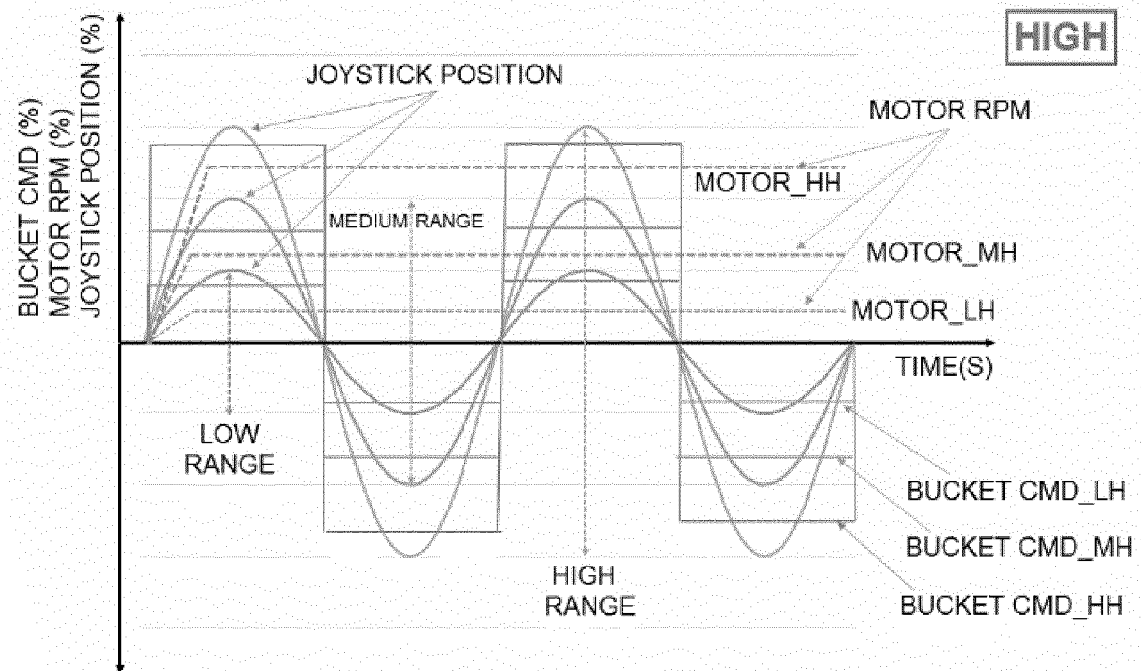


Fig. 3

	LOW	MEDIUM	HIGH
Joystick Range Low	Bucket CMD_LL	Bucket CMD_LM	Bucket CMD_LH
Joystick Range Medium	Bucket CMD_ML	Bucket CMD_MM	Bucket CMD_MH
Joystick Range High	Bucket CMD_HL	Bucket CMD_HM	Bucket CMD_HH

	LOW	MEDIUM	HIGH
Joystick Range Low	Motor_LL	Motor_LM	Motor_LH
Joystick Range Medium	Motor_ML	Motor_MM	Motor_MH
Joystick Range High	Motor_HL	Motor_HM	Motor_HH

Fig. 4



EUROPEAN SEARCH REPORT

Application Number

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The present search report has been drawn up for all claims			

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EPO FORM 1503 03:82 (P04C01)

Place of search

Munich

Date of completion of the search

30 November 2022

Examiner

Díaz Antuña, Elena

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

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5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
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