United States Patent

[11] 3,593,519

[72] Inventor Paul Fuhrimann
Romanshorn, Switzerland

[21] Appl. No. 832,066
[22] Filed June 11, 1969
[45] Patented July 20, 1971
[73] Assignee Hydrel A. G. Maschinenfabrik
Romanshorn, Switzerland
[32] Priority Sept. 10, 1968
[33] Switzerland
[31] 13690/68

[54] **DEVICE FOR PRECISION REVERSING IN A MANNER SUBSTANTIALLY INDEPENDENT OF LOAD, FOR USE IN A HYDRAULIC POWER DRIVE FOR RECIPROCATING MOVEMENTS, FOR INSTANCE FOR MACHINE TOOLS AND ELEVATORS**

11 Claims, 4 Drawing Figs.

[52] **U.S. Cl.** .... **60/52 R,** 60/53, 60/DIG. 2, 60/52 VS, 60/52 HD

[51] **Int. Cl.** **F15b 15/18,** F15b 15/22

[50] **Field of Search** .... 60/52 VS, 53, 52 R, 52 HD

[56] **References Cited**

UNITED STATES PATENTS

1,948,951	2/1934	Walker	60/E UX
2,299,686	10/1942	Ernst	60/E UX
2,324,727	7/1943	Shartle	60/52
2,388,369	11/1945	Shendrick	60/E UX
2,419,563	4/1947	Kaser	60/52 HF

Primary Examiner—Edgar W. Geoghegan
Attorney—Karl F. Ross

ABSTRACT: A system for the precision reversal of the motion of a movable member, such as an elevator, connected to a hydraulic motor. The movable member is provided with a pair of reversing surfaces so shaped as to determine braking distance, reversing point and reacceleration characteristics and cooperating with a feeler which transmits a signal through an amplifier to a servo valve for switching a pump.

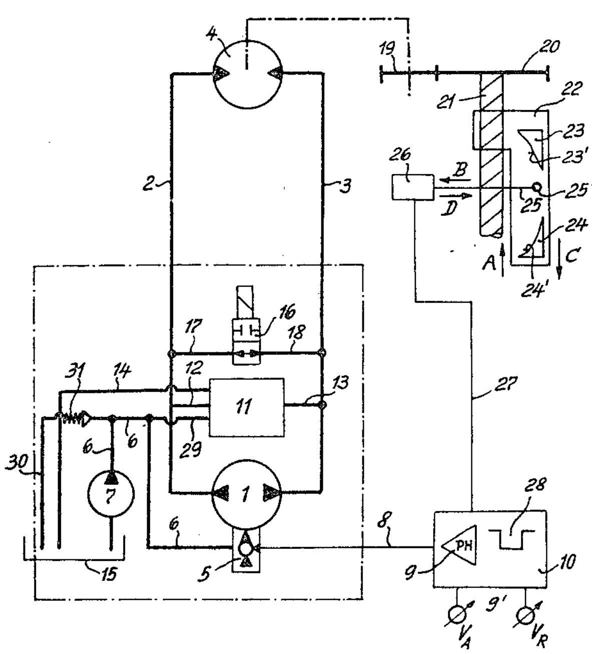
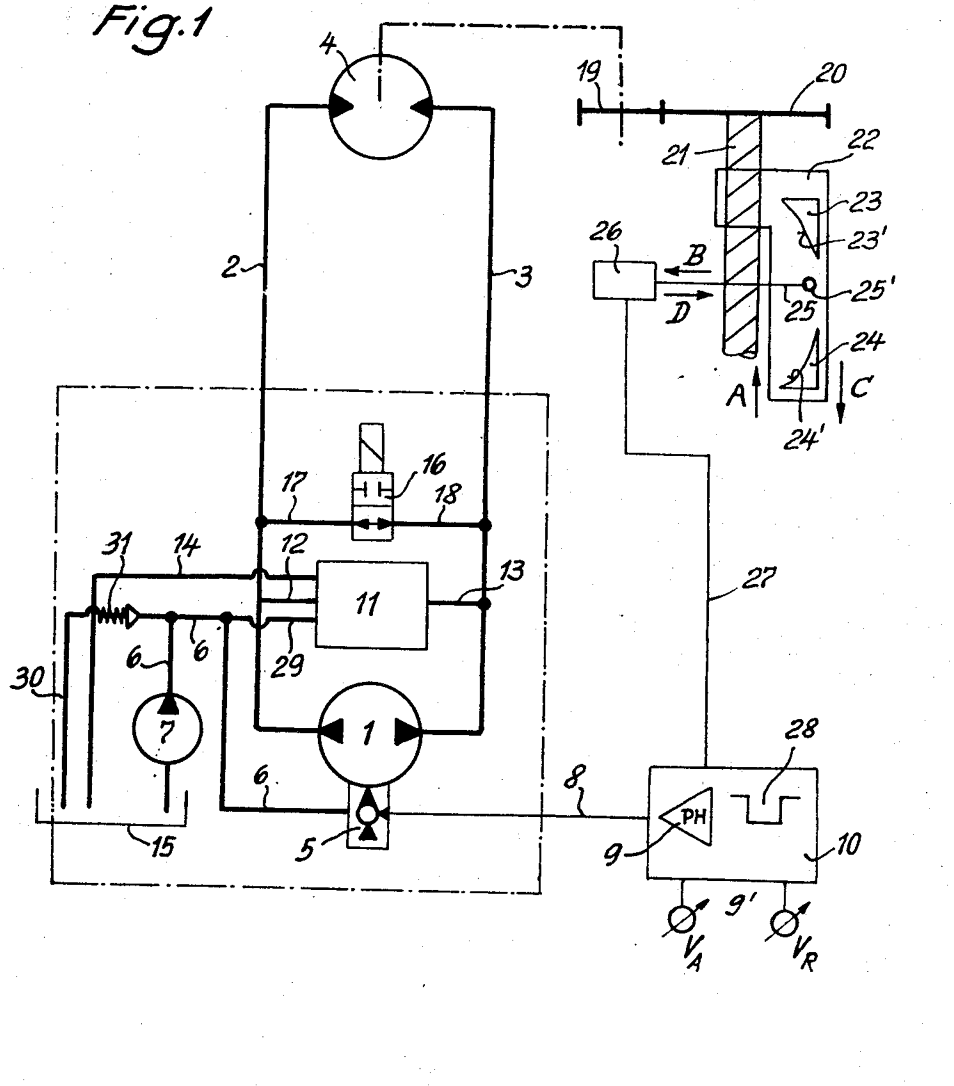


Fig.1



PAUL FUHRIMANN
INVENTOR.

BY Karl G. Ross

ATTORNEY

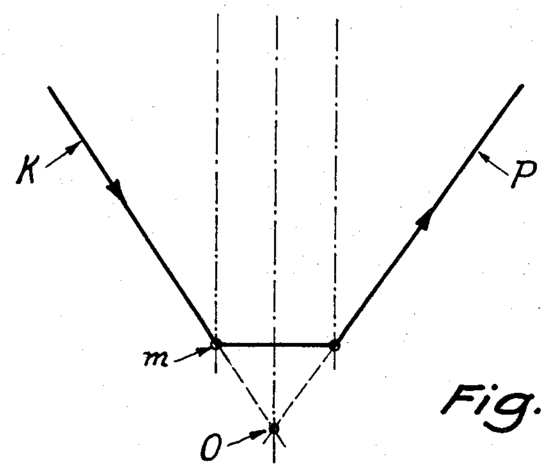


Fig. 2

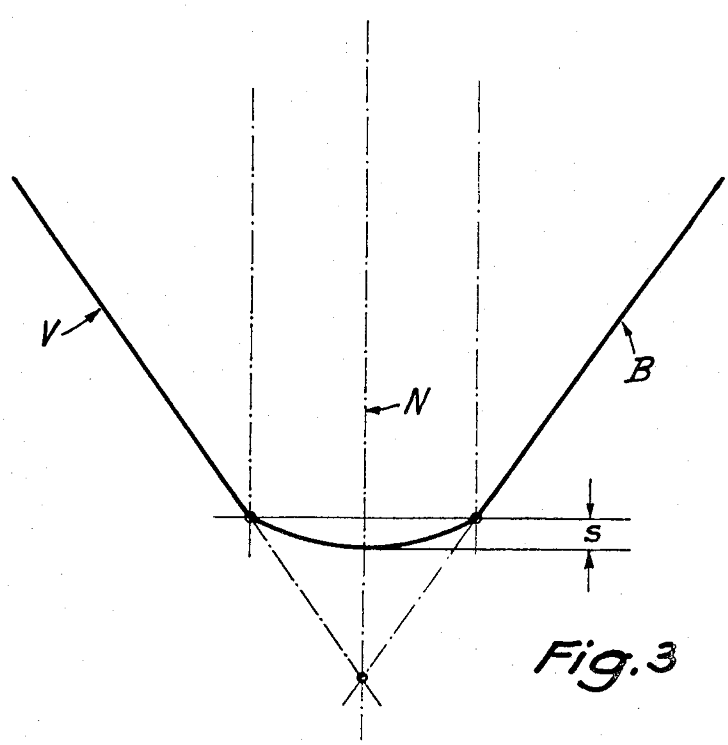


Fig. 3

PAUL FUHRIMANN
INVENTOR.

BY Karl F. Ross
ATTORNEY

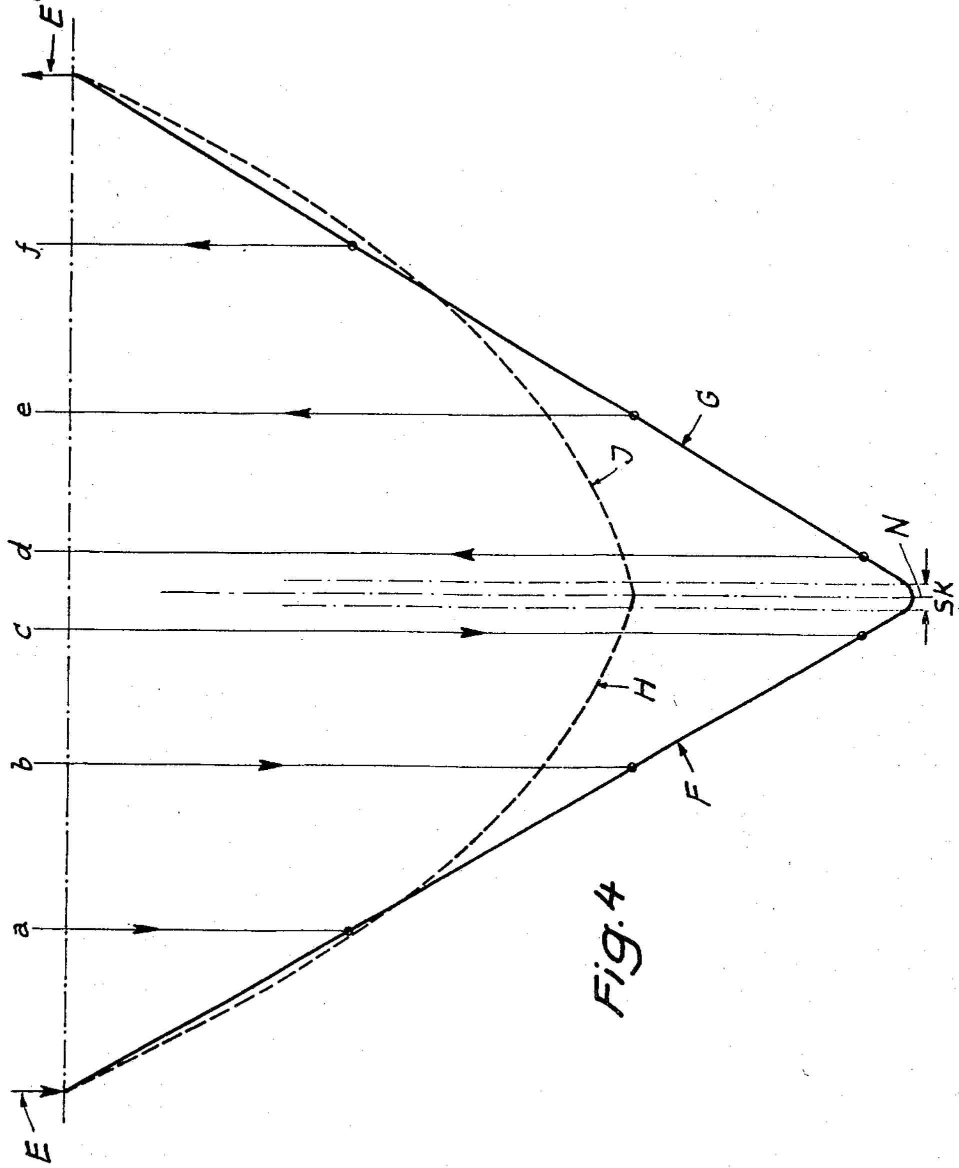


Fig. 4

PAUL FUHRIMANN
INVENTOR.

BY Karl F. Ross
ATTORNEY

DEVICE FOR PRECISION REVERSING IN A MANNER SUBSTANTIALLY INDEPENDENT OF LOAD, FOR USE IN A HYDRAULIC POWER DRIVE FOR RECIPROCATING MOVEMENTS, FOR INSTANCE FOR MACHINE TOOLS AND ELEVATORS

This invention relates to a device for precision reversing in a manner substantially independent of load, for use in an hydraulic power drive for reciprocating movements, for instance for machine tools and elevators, having a main oil pump delivering through the idle point in both drive directions alternately for the drive of a rotary hydraulic motor or a double-acting piston-and-cylinder motor with rapid reversing of the movement and ascertainment of an accurate reversing point of the movable element of the motor depending on the running distance covered by said movable element and on the shape and location of adjustable control elements, and further having a servo oil circuit with servo pump allocated to the main oil pump and a voltage-dependent electrohydraulic servocontrol valve for controlling the reversing movement of the main oil pump.

Precision reversing devices, for instance for machine tools with straight line metal removal such as slotting and parallel-planing machines, are known per se, but the amount of electronic equipment required for numerical control is very considerable and expensive even when combined with conventional hydraulic drives.

The present invention solves the problem by far simpler means by providing reversing surfaces on the reciprocating machine or elevator part or on a tup connected to and moving with it for the purpose of establishing the reversing characteristic including the braking distance, reversing point and reacceleration distance, and by placing the middle of the path of these reversing surfaces a feeler of an electric control member that is actuating by said surfaces. The control member is connected via an electronic amplifier to an solenoid of the electrohydraulic servo valve for the purpose of transmitting electric values of the member corresponding to the momentary position of the reversing surfaces relative to the feeler. The arrangement is such that every point of contact between the feeler and the reversing surface corresponds in the control member to a definite capacitive, inductive or voltage value, which values are transmitted via the electronic amplifier to the electrohydraulic servo valve which in turn controls the oil-driving pump, equipped for regulation through the idle point, in respect to the required delivery quantities, within the range of the freely adjustable maximum speeds of the motor both for forward and reverse motion.

The accompanying drawing shows diagrammatically a preferred embodiment of the precision reversing device according to the invention.

FIG. 1 is a diagram of the installation;

FIG. 2 is a diagrammatic representation of the variations of voltage in the servo valve during the reversing phase;

FIG. 3 is a graphic representation of the pump delivery during the reversing phase, and

FIG. 4 is a displacement velocity diagram in the reversing range of the reciprocating machine or elevator part or of the tup.

Referring to FIG. 1, numeral **1** designates a main oil pump delivering in both directions of rotation and reversing through its idle or "null" point. It communicates through pipes **2** and **3** with an hydraulic motor **4**. Main oil pump **1**, pipes **2** and **3** and hydraulic motor **4** form a closed circuit. Main oil pump **1** is equipped with a voltage-controlled servovalve **5** which, on the one hand communicates through a pipe **6** with an auxiliary or control oil pump **7** and, on the other hand, is connected through an electric lead **8** to the electronic amplifier **9** of an electronic set **10** which is equipped with a pair of velocity regulators **9'**, one each for the working velocity VA and the return velocity VR. With these regulators, the two velocities that may be required in any given case can be set in the form of maximum values.

Numeral **11** designates a feed and flushing block **11** of known design connected in parallel with the main oil pump **1**, which communicates through pipes **12** and **13** with pipes **2** and **3** leading to hydraulic motor **4**. An overflow pipe **14** leads from the feed and flushing block **11** to the oil tank **15**. The bypass valve **16** is connected in parallel with the main oil pump **1** and is connected by pipes **17** and **18** to pipes **2** and **3** leading to hydraulic motor **4**.

The hydraulic motor is connected by gears **19** and **20** to a screw spindle **21** adapted to serve as a drive for a tup **22** or for the reciprocating part of the machine or elevator. Control elements **23** and **24** are arranged on the tup or the machine or elevator part (driven member) **22** so that they can be displaced and fixed in the desired position.

Each of the control elements has a specially designed control surface **23'** and **24'** respectively, into the path of which the end **25'** of a linearly movable feeler **25** projects. Feeler **25** is in interacting connection with a linear potentiometer **26** of the transducer means which is connected through an electric lead **27** to the electronic block **10** including, in addition to the amplifier set **9**, a voltage seesaw device **28**. A pipe **29** branching off from control oil pump **7**, or more exactly from pipe **6** of the latter, leads to the feed and flushing block **11**. A second pipe **30** with a pressure relief or nonreturn valve **31** is also connected to control oil pump **7**, or more exactly to pipe **6**, and leads into the oil tank **15**.

Suppose now the main oil pump **1** delivers pressurized oil through pipe **2** to hydraulic motor **4**, and let us further assume that the tup **22** is thereby moved through gear **19** and **20** and screw spindle **21** in the direction of arrow A (FIG. **1**) at a maximum constant speed set by the velocity regulator **9'** shown in FIG. **1**. When tup **22** has covered the free path between reversing elements **23** and **24**, reversing surface **24'** runs up against the end **25'** of feeler **25**, so that the feeler is displaced in the direction of arrow B. As a result a change in voltage is brought about in linear potentiometer **26**. This voltage change acts through the electric lead **27**, the amplifier set **9** and a solenoid of servo valve **5** to regulate the pressure of the oil supplied by auxiliary pump **7** to the servo valve for the adjustment of the eccentricity (displacement) of the main oil pump **1**, which can be regulated both with respect to its delivery quantity and to the direction of delivery. In other words, the comparatively small change in electric voltage of the linear potentiometer is converted by amplifier set **9** and servo valve **5** into a correspondingly large mechanical force which moves the main oil pump into the desired swivel position so that the delivery of the pump falls almost to zero, whereupon the pump, reaching the tripping point, springs in the opposite direction and now forces pressurized oil through pipe **3** to hydraulic motor **4**. The result of this is that the gear **19** and **20** and the screw spindle **21** now turn in the opposite direction and displace tup **22** in the direction of arrow C. Feeler **25,25'** which has been in contact with reversing surface **24'** now moves under spring action in the direction of arrow D, whereupon control values are again transmitted by linear potentiometer **26** through pipe **27**, amplifier set **9** and electric lead **8** to the servo valve **5** in the sense of an increase of delivery and thus a corresponding acceleration of the movement of tup **22**. As the reversing surface **23'** runs up against the end **25'** of feeler **25**, the reversing process described is repeated.

The feed and flushing block **11** ensures the replacement of the leakage loss of oil due to the pressure in the closed oil circuit **1**, **2**, **3** and **4** and an exchange of oil, and therewith the venting of oil pipes **2** and **3** which are alternately under pressure and not, so as to prevent overheating of the oil although it is exposed to constant pressure impacts and is in reciprocating movement. Feed and flushing block **11** further include two pressure relief valves directed counter to each other which allow any excess pressure to escape alternately into one of the pipes **2** and **3** which happens not to be under pressure. Especially during braking of the hydraulic driving pump and any additional braking of the hydraulic motor **4**, the bypass valve **16** has as its purpose to ensure the balancing of any small quantity of oil that may still be flowing when the main pump 1 is out of operation, but because of certain inaccuracies a very small amount of oil should be supplied to the hydraulic motor.

While the adjustably arranged reversing elements 23 and 24 determine the length of height of stroke of tup 22, and owing to the special profile of reversing surfaces 23' and 24' likewise the braking and reacceleration characteristic, the voltage seesaw device 28 serves both to skip the zero-voltage point = zero-velocity point of the last braking and first reacceleration phase and thus also to prevent the effective zero voltage from being reached, while at the same time supplying the necessary initial voltage for reacceleration.

In FIG. 2 the variations of voltage in the servo valve are shown graphically. Line (branch) K shows the drop in voltage as the tup runs up against the reversing surface. At point *m* the voltage seesaw device comes into action, at a voltage value in the servo valve of at least about 1 percent of the maximum voltage. 0 denotes the point of zero voltage, while P is the rise of the voltage after reversing has taken place.

In FIG. 3 the pump delivery corresponding to the voltage variation of FIG. 2 is represented graphically, line (branch) V being the drop in delivery as a result of the slowing of the speed as caused by the reversing surface, while line (branch) B shows the increase in the pump delivery in the acceleration phase. The reversing path during the tripping over of the voltage is designated *s*.

In FIG. 4 the velocity curve is shown graphically in a solid line for uniform braking and acceleration, the straight lines E and E' holding good for constant velocities of the tup when the reversing elements 23 and 24 are outside the range of feeler 25,25'. The oblique straight line F shows the velocity controlled by potentiometer 26 and falling almost to the zero line N during the braking process, while the oblique straight line G represents the corresponding reacceleration phase. Sk marks the bridging phase when the voltage trips over. If in FIG. 4 the velocity E till the commencement of braking is 90 meters per minute, for instance, it will be only 60 meters per minute at point *a*, 30 meters per minute at point *b* and 6 meters per minute at point *c*. After the zero line N has been crossed, acceleration begins in the reverse direction of operation. The velocity at point *d* is 6 meters per minute, at *e* 30, at *f* 60 and at E' reaches the normal level of 90 meters per minute.

As FIG. 4 further shows, with linear control of the curve by the potentiometer the braking and reacceleration phases run out in a fairly long peak. This peak can be considerably shortened by using a parabolic or sinusoidal curve. The course taken by braking and reacceleration in this case is shown in FIG. 4 by the curves H and J. A similar effect is obtained if the profile of the reversing surfaces is shaped in accordance with an exponential curve with an exponent greater than unity.

An axial-pison-type pump can be used advantageously for the main oil pump 1, while a piston-and-cylinder system may be used instead of the hydraulic motor 4.

Alternatively, it is possible to use some other electric control member instead of the linear potentiometer, for instance a capacitively regulable condenser or an inductor supplying variable inductive values.

As for the reversing surfaces 23' and 24', their profile may be shaped in various ways, for instance as an oblique straight line or, as already mentioned, as an exponential curve. It might also be conceivable to have the profiles of the reversing surfaces designed in sinusoidal or parabolic form or to combine some of these different profiles.

I claim:

1. A system for the precision reversal of the motion of a movable member substantially independently of a load thereon, said system comprising:

a hydraulic motor connected to said load for reciprocating same;

a main oil pump connected in a fluid circuit with said hydraulic motor and having two fluid drive directions separated by an idle point for powering said hydraulic motor in opposite directions;

a servo oil circuit including a servo pump, an electrically operated servocontrol valve connected to said servo pump and to said main oil pump for reversibly switching same between said directions through said idle point, and transducer means for transforming a mechanical movement into an electrical signal applied to said valve; and

a pair of reversing surfaces fixed on said member for establishing a reversing characteristic relating the braking distance, reversing point and reacceleration distance of said member, said transducer means including an electric control feeler actuated by said surfaces and disposed between them, said surfaces and feeler being so constructed and arranged that each point of contact of said feeler with said surfaces corresponds to an electrical parameter transmitted to said valve for controlling said main oil pump through said idle point to deliver corresponding quantities of a fluid medium to corresponding sides of said motor.

2. The system defined in claim 1 wherein said electric control feeler includes a capacitively regulatable condenser.

3. The system defined in claim 1 wherein said feeler includes an inductor for producing a variable inductance value.

4. The system defined in claim 1 wherein said feeler includes a movable element of a linear potentiometer, said transducer means further comprising an electronic amplifier connected between said potentiometer and said valve.

5. The system defined in claim 4 wherein said surfaces are each oblique but linear.

6. The system defined in claim 4 wherein said surfaces lie along exponential curves.

7. The system defined in claim 4 wherein said surfaces lie along a sine curve.

8. The system defined in claim 4 wherein said surfaces lie along generally paraboloidal curves.

9. The system defined in claim 4 wherein each of said surfaces lies along a respective composite curve consisting of a plurality of shapes including a straight line, a sinusoid, a parabola and an exponential curve.

10. The system defined in claim 1, further comprising a control element mounted on said member and carrying said surfaces, said control element being movable relatively to said member and said feeler and being adapted to be secured to said member in a selected one of a number of positions.

11. The system defined in claim 1 wherein said transducer means includes a voltage seesaw device adapted to skip the electrical signal value corresponding to the zero-velocity point of said member and to switch over directly to an electrical parameter producing reacceleration.