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(54) Abstract Title
A motor vehicle with electric drive and friction braking

(57) Braking of the vehicle is controlled by an electronic friction braking control unit 200 which transmits a (desired) braking moment, for regenerative deceleration, to a motor control unit (not shown) via a bus system 206, and which receives from the motor control unit the actual moment which has been set therein. Initial brake pedal movement (T0-T1, Figure 6a) results in the electric drive motor(s) applying regenerative braking to the driven wheels, and very little or zero friction braking achieved by opening outlet valves 126, 128 so that pressure medium flowing to the wheel brake cylinders is conducted into storage chambers 132. For panic braking, judged by pedal speed, the outlet valves do not open. If the battery is fully charged, friction braking may be increased by activating pumps 136. For anti-lock control the drive motor(s) may be switched briefly to drive.

Fig. 1

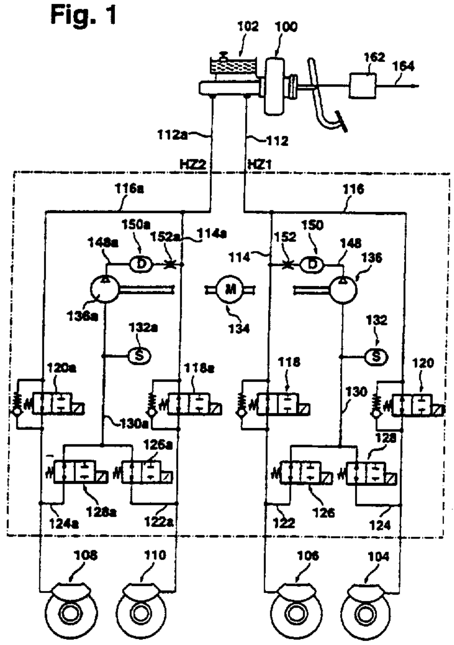

Fig. 3

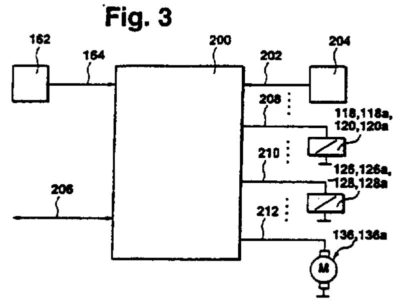

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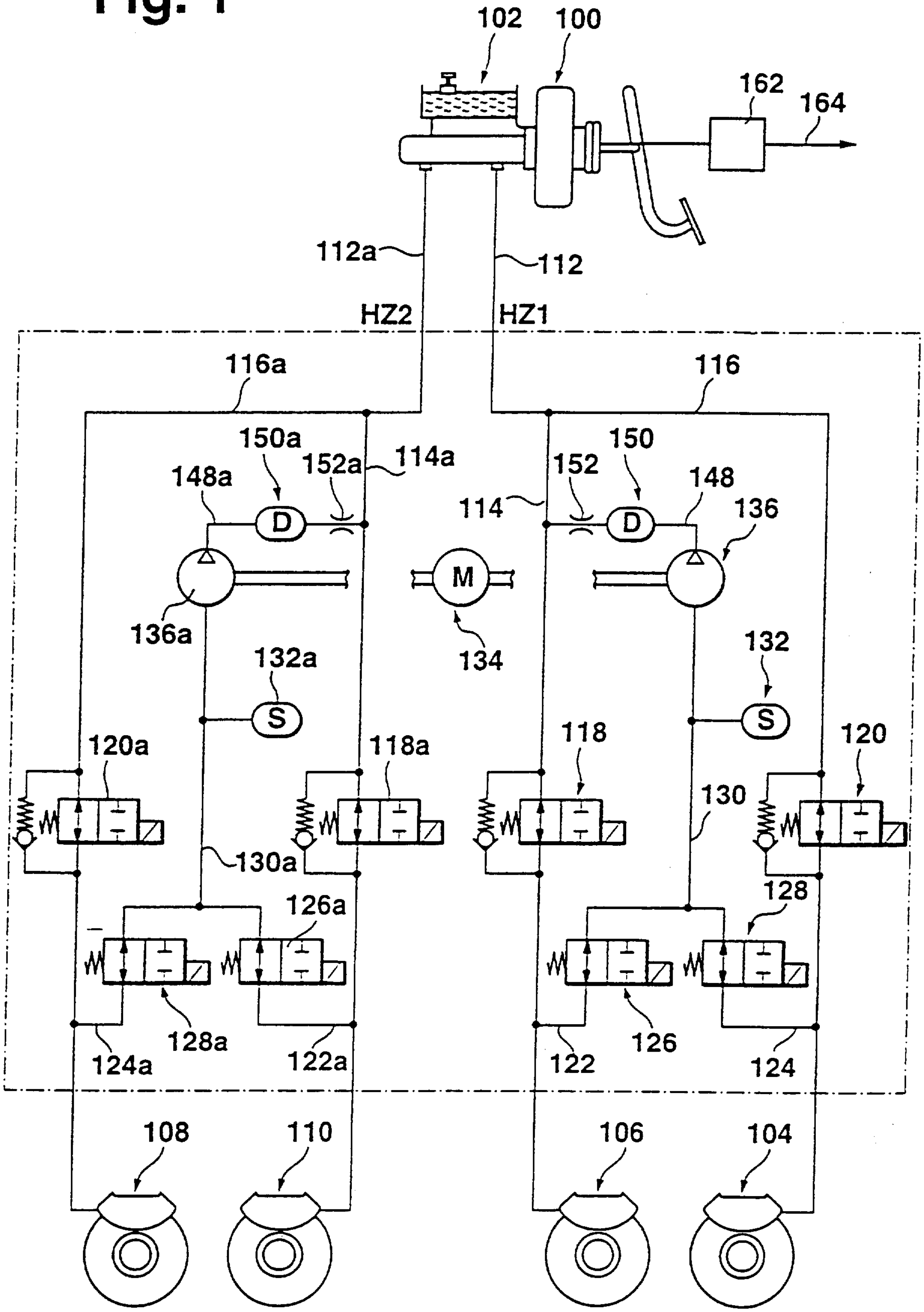
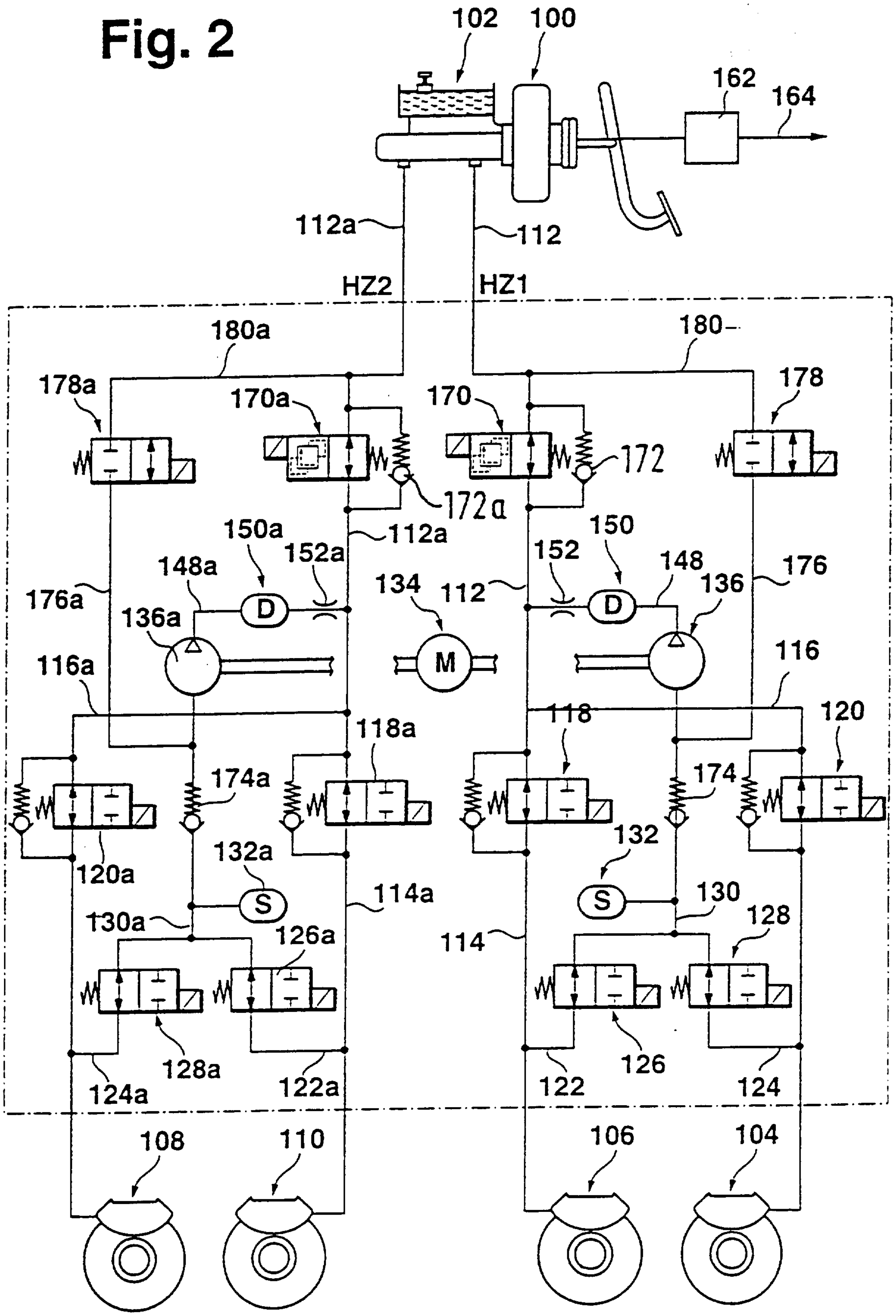
Fig. 1



102
100
162
164
112a
112
HZ2
HZ1
116a
116
150a
152a
114a
148a
114
152
150
148
136
D
D
M
136a
134
132a
132
S
S
120a
118a
118
120
130
130a
128
126a
128a
126
124a
122a
122
124
108
110
106
104

Fig. 2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100
162
164
112a
112
HZ2
HZ1
180a
180
178a
170a
170
178
172
172a
150a
112a
150
152a
152
148a
148
176a
176
134
112
136
136a
M
116a
116
118a
118
120
174a
174
120a
132a
132
114a
130
130a
128
126a
114
128a
126
124a
122a
122
124
108
110
106
104

Fig. 3

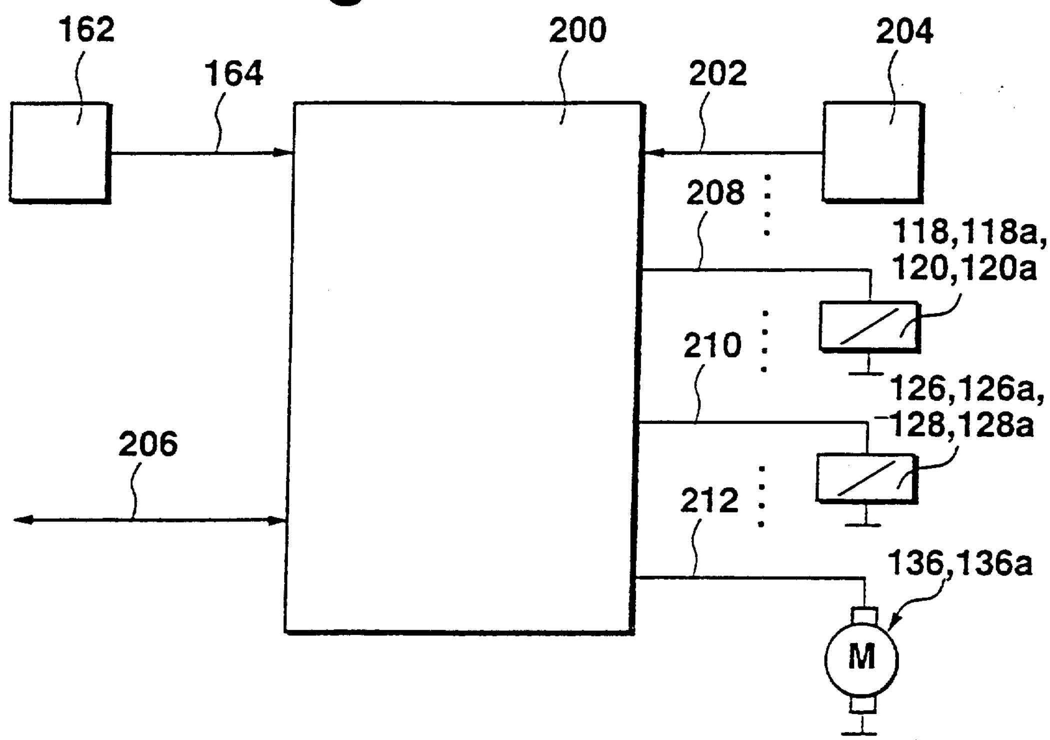

162
164
200
202
204
208
118,118a,
120,120a
210
126,126a,
128,128a
206
212
136,136a
M

Fig. 5

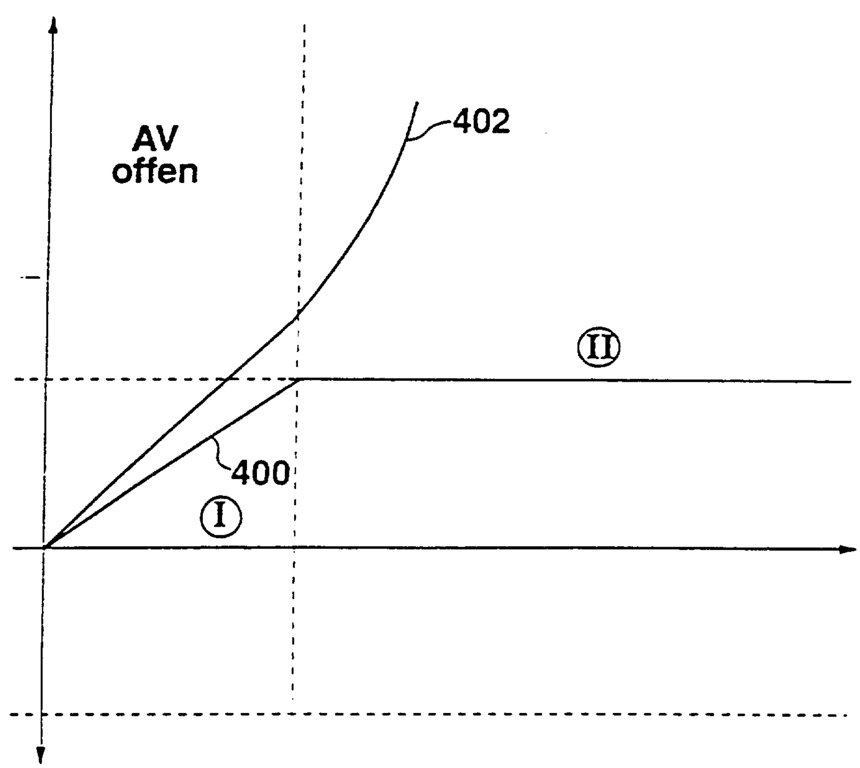

AV
offen
402
II
400
I

Fig. 4

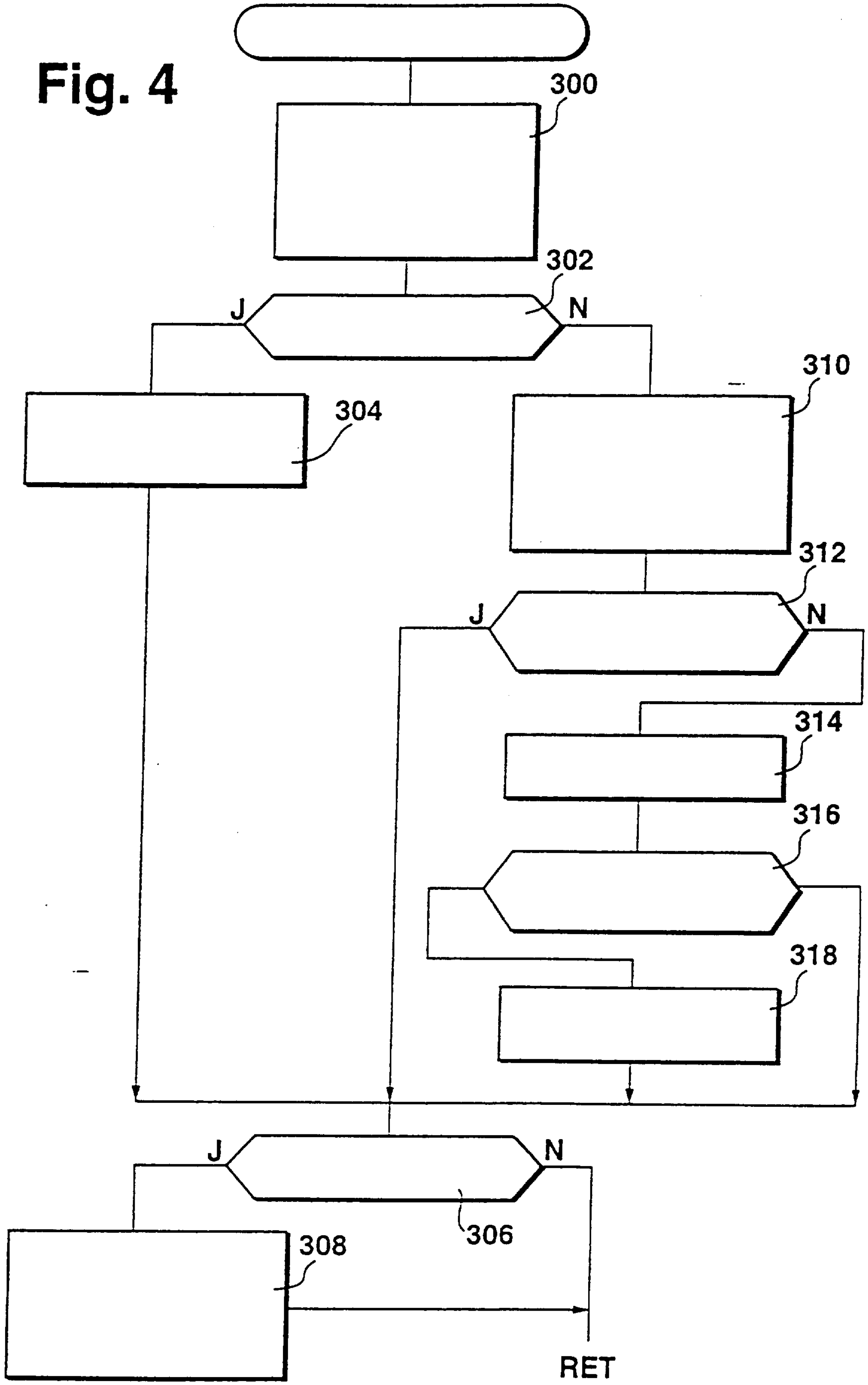


Fig. 6a

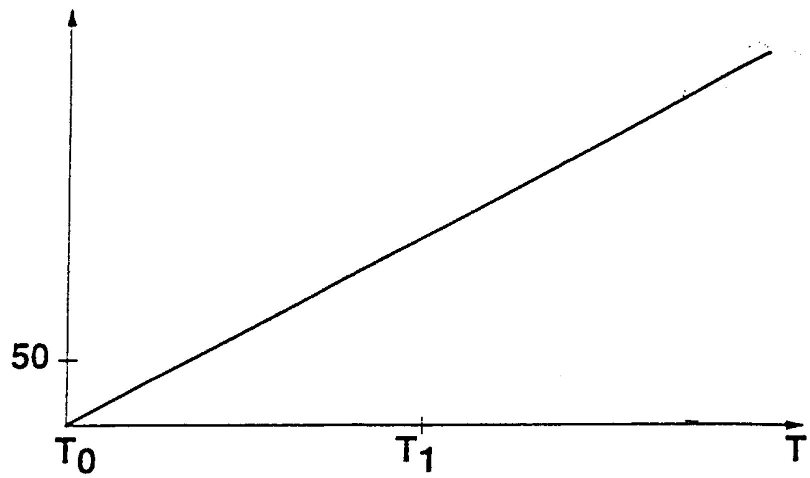


Fig. 6b

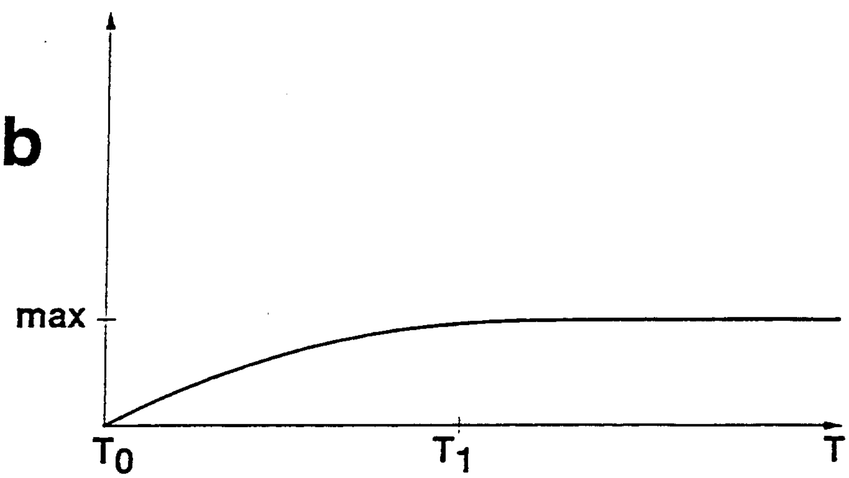
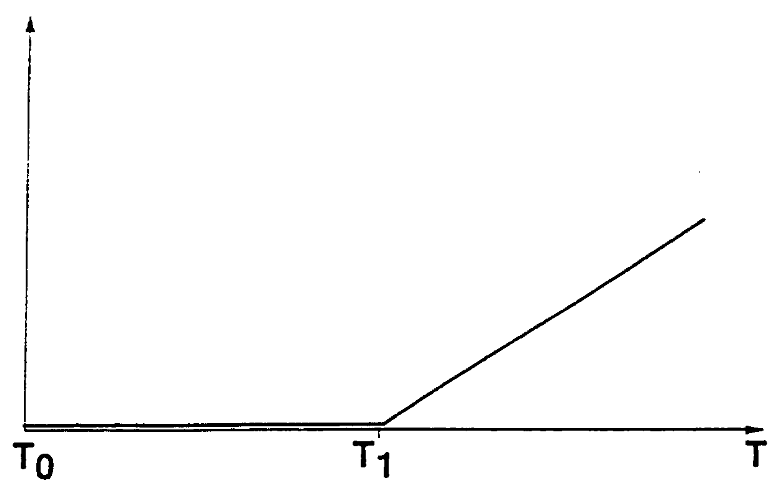


Fig. 6c



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Device for controlling the braking installation of motor vehicles with electric drive

Prior art

The invention relates to a device for controlling the braking installation of vehicles with electric drive, in accordance with the pre-characterising clauses of the independent patent claims.

A device of this kind is known, for example, from EP-A 595 961. The latter describes a braking installation for a vehicle with electric drive which comprises a conventional braking system provided with hydraulically actuated friction brakes, and an electro-regenerative braking system. Under these circumstances, the electro-regenerative braking system utilises the electric driving motor or motors of the motor vehicle for deceleration and for the recovery of energy during a braking operation. The share of the braking force accounted for by the hydraulic friction brakes is appropriately adapted, during a braking operation, to the behaviour of the regenerative braking system in order to achieve optimum recovery of energy. To this end, the braking force to be set is determined at the driving wheels from the degree of actuation of the brake pedal, while the non-driven wheels are braked in the conventional manner via the hydraulics in direct dependence on the actuation of the pedal. As regards the driving wheels, that maximum share of the braking force accounted for by the regenerative braking system which is usable in the current operating condition is ascertained from operating quantities, and the predetermined braking force is set by appropriate activation of the driving motor. If the braking force required exceeds the maximum usable share of the braking force, the excess share of the braking force is set by the friction brake.

Since provision is made for decoupling the hydraulics from actuation of the pedal as regards the driving wheels, while conventional direct hydraulic control exists for the non-driven wheels, the known design represents an expensive redesign of the braking installation and its components.

The object of the invention is to indicate measures for controlling the braking installation of a vehicle provided with electric drive, in which, while using a conventional hydraulic or pneumatic friction braking system, optimum harmonisation between the regenerative deceleration via the electric motor and the friction braking is achieved, so that as much energy as possible can be recovered.

The present invention provides a device for controlling the braking installation of a vehicle with an electric drive, with at least one electric motor as the drive unit, with a friction brake system, with an electronic control unit which controls the brake, with a motor control unit which controls the electric motor, wherein the electronic control unit for the friction brake transmits an ideal braking moment for the regenerative deceleration of the vehicle to the motor control unit via the bus system, while the motor control unit transmits to the brake control unit the actual moment which has been set.

Advantages of the invention

Through the preferred method and apparatus according to the invention, the potential of regenerative deceleration is utilised in the optimum manner in electric vehicles or in vehicles with hybrid drive, without the need to modify a conventional braking installation.

A particular advantage, in this connection, is that the electric driving motor or motors recover as much energy as possible when deceleration occurs. Braking requirements which go beyond the regenerative deceleration may be covered by a conventional friction brake system.

In a particularly advantageous embodiment of the invention, the friction brake system acts on all the wheels of the vehicle when the electrical installation is switched off. This guarantees the operational safety of the vehicle.

A particular advantage is that the pedal force may remain small when use is made of a conventional braking installation with components for the drive slip-regulating function.

Further advantages will emerge from the description of exemplified embodiments and also from the dependent patent claim.

Drawings

The invention will be described in greater detail below with the aid of the forms of embodiment represented in the drawings. In the latter, figures 1 and 2 show two exemplified embodiments of a conventional hydraulic braking installation with an ABS or ABS/ASC function. Figure 3 shows an electronic control unit with input and output signals for controlling the braking installation of the vehicle with electric drive. Outlined in figure 4 is a flow chart which represents the implementation of the method according to the invention in the form of a computing programme. Finally, figures 5 and 6 represent, with the aid of charts, the mode of operation of the method and apparatus according to the invention.

Description of exemplified embodiments

Figure 1 shows a conventional hydraulic braking installation with an ABS function. In this installation, two wheel brakes, in each case, of the two-axle vehicle are combined in a braking circuit (HZ1, HZ2). The braking installation has a dual-circuit main brake cylinder 100 which can be actuated by a pedal and has a pressure medium reservoir 102. For carrying out the regenerative deceleration, there is provided at the brake pedal 101 at least one measuring arrangement 162 which emits, via its output line 164, a measurement for the degree of actuation or force of actuation of the brake pedal by the driver.

The first braking circuit (HZ1) is connected to the wheel brakes 104 and 106 of, for example, the non-driven wheels. The wheel brakes 108, 110 of, for example, the driven wheels, are linked up to a second braking circuit (HZ2). Since, in the example of a conventional braking installation represented in figure 1, the two braking circuits are of essentially identical composition, only the first braking circuit (HZ1), the components of which have their counterparts in the second braking circuit and are designated, in each case, by the supplement a to the reference symbol, will be described below. A brake line 112 emanating from the main brake cylinder branches into two brake lines 114 and 116 leading to the wheel brakes 106 and 104. Inlet valves 118 and 120, which have a spring-actuated conducting position and an electromagnetically switchable blocking position, are provided in the brake lines 114 and 116 respectively. Emanating from the individual brake line in each case, between the inlet valves and the wheel brakes, is a return line 122 and 124 respectively. An outlet valve 126 and 128 is disposed, in each case, in these return lines. The outlet valves have a spring-actuated blocking position and an electromagnetically switchable conducting position. The return lines 122 and 124 are joined together in a return line 130, linked up to which is a storage chamber 132. In addition, the braking circuit has a high pressure-generating pump 136 which is driven by an electric driving motor 134. This pump is connected, on the intake side, to the return line 130. On the output side, the pump 136 is connected, by a delivery line 148 to the brake line 114 between the main brake cylinder and the inlet valve 118. A damping chamber 150 and a throttle 152 are disposed in the delivery line 148.

During normal operation, the valves are in their non-activated basic position. This means that the inlet valves 118 and 120 are open and the outlet valves 126 and 128 are closed. As a result, the corresponding wheel brakes are acted upon by the pressure fed in by the driver as a result of actuation of the pedal. In an ABS situation, the outlet valves are opened and the pump activated in order to reduce pressure from the wheel brake or brakes concerned.

A hydraulic braking installation which, through additional components, also permits an ASC function in addition to ABS, is represented in figure 2.

In the braking installation illustrated in figure 2, a so-called "switch-over valve" 170, which is bridged by a pressure-limiting valve 172, is located in the brake line 112. The switch-over valve has a spring-actuated conducting position and an electromagnetically switchable blocking position. Also disposed in the line between the storage chamber 132 and the pump 136 is a non-return valve which prevents negative pressure from occurring in the wheel brake cylinders when the outlet valve is opened. On the suction side, there is fed to the pump 136, in addition to the return line 130, an intake line 176 in which an intake control valve 178 with a spring-actuated blocking position and an electromagnetically switchable conducting position is inserted. This intake valve is connected to the brake line 112 via a line 180.

If the driving wheels of the vehicle have an excessive degree of drive slip, the corresponding switch-over valve is switched into its blocking position, and the intake valve into its conducting position. By activating the pump, pressure medium is drawn in from the reservoir 102 without actuation of the pedal and fed into the wheel brake cylinder or cylinders concerned via the open inlet valve. As a result, pressure can be built up in the wheel brakes independently of actuation of the brake pedal. The reduction of pressure takes place, as in the example illustrated in figure 1, as a result of the opening of the outlet valves, or the closing of the intake valves and opening of the switch-over valves.

In addition to the hydraulically actuated friction brakes represented in figures 1 and 2, regenerative braking via the electric motor or motors used for driving purposes is possible in the context of the electric or hybrid vehicle. In this case, the electric motor is activated as a generator for charging the batteries. Under these circumstances, the motor is, as a rule, provided with a control unit of its own for controlling the electric drive. This is connected to the control unit controlling the hydraulic braking installation.

Figure 3 represents an example of such a control unit. The control unit 200 receives, via an input line 164, a measurement for actuation of the brake pedal and, via a line 202, quantities regarding the wheel speeds of the vehicle wheels from measuring arrangements 204. Also provided is a connecting line 206, preferably a serial bus, to the motor control unit, via which bus the control unit 200 receives a quantity representing the braking moment set by the regenerative brake, and emits a quantity representing the braking moment to be set. Also present are output lines 208, 210 and 212 for controlling the inlet valves 118 and 120, the outlet valves 126 and 128, and also the pump 136.

The aim of the invention is to recover as much as possible of the energy which occurs during deceleration in electric or hybrid vehicles. Since the regenerative deceleration via the driving motor of the vehicle is not sufficient to cover all the braking requirements of the vehicle, the latter must additionally be equipped with a friction brake system. The regenerative deceleration and the friction braking are to be harmonised with one another in such a way that as much energy as possible can be recovered.

The decelerations from the friction braking and the regenerative braking are coordinated in the computing element which the control unit comprises and of which there is at least one. To this end, at least one signal, which indicates the actuation of the pedal, is fed to the control unit. If the electrical installation is in operation, the electric motor or motors can effect deceleration. At the start of braking, with actuation of the brake pedal, the valves in the hydraulic braking installation are therefore activated in such a way that there takes place in the wheel brake cylinders no build-up of braking pressure, or only a slight build-up of such pressure, which leads to no braking action, or to no appreciable braking action compared to the brake effect provided by the regenerative braking. This is preferably carried out by opening the outlet valves, under which circumstances the pressure medium fed into the wheel brakes as a result of actuation of the pedal by the driver flows back into the storage chamber 132. The driver's desire for deceleration is deduced dependent on actuation of the brake pedal and, optionally, of other operating quantities. The said desire is converted, in a manner known from the prior art, into an ideal motor moment which is transmitted to the motor control unit via a bus. The motor control unit then sets the desired braking retardation. As soon as the storage chamber is full, braking pressure is built up in the wheels, in addition to the regenerative deceleration, if the desire to brake goes beyond this point, and a superimposed deceleration by the friction brake system is thus achieved, as predetermined by the driver.

In order to shorten the pedal travel, it is possible, in an advantageous exemplified embodiment, to close the outlet valves when the storage chamber is partially full and, in this way, to cause the friction brake to act even at a shorter pedal travel.

Through the invention, the known pedal characteristics are maintained for the driver. In particular, no hard pedal behaviour is produced in the regenerative deceleration range in spite of the low braking pressure, which corresponds to the counter-pressure of the storage chamber.

This fundamental mode of procedure must be corrected in some operating conditions.

In most cases the electric drive acts on only one axle, and the regenerative deceleration therefore also acts only on this axle. This means that the distribution of braking force between the front and rear axle is not uniform, but fluctuates depending on the share accounted for by regenerative deceleration. For most decelerating operations, this behaviour does not constitute a problem. But in the case of decelerating operations in situations of danger or borderline situations, a distribution of braking force which is uniform, or can be preselected in a calculated manner, is advantageous. The control apparatus therefore does not open the outlet valves when such situations are identified at the start of braking. The friction brake system effects braking immediately, so that the predetermined distribution of braking force is guaranteed. Braking situations of this kind are constituted, for example, by so-called "panic" braking operations, which can be deduced, *inter alia*, from the speed of actuation of the brake pedal.

There are also operating situations in which the share accounted for by regenerative deceleration must be reduced. This is the case, for example, when the battery is full, the charging output over time is too high or, as a result of a change in the speed of the vehicle, the dependence of the braking moment of the motor on the speed of the vehicle affects the overall deceleration. In these operating situations, the overall deceleration would be reduced unless the driver changes the travel of the pedal. Since provision may be made, according to an embodiment of the invention, for the control unit of the electric drive to report back the motor moment, which is set on an instantaneous basis, to the brake control unit, in such cases the outlet valves are closed, provided they are still open, and the pump started. As a result, the volume of fluid which has accumulated in the storage chamber is brought back into the braking circuit again. In this way it is possible, without changing the travel of the pedal, to increase the share accounted for by the friction brake system.

In order to prevent the necessary pedal force at the driver's foot from being increased as a result, provision is made, in a braking installation as illustrated in figure 2, for the switch-over valve, too, to also be activated, in addition to the pump, in operating situations in which the share accounted for by the friction brake system is increased, so that the braking pressure in the wheel can be increased without the counter-force at the pedal increasing.

If none of these special operating situations exists, the outlet valves are closed, in the preferred exemplified embodiment, in accordance with a correlation, which is deposited in the control unit, between the degree of filling of the storage chamber and the pedal travel. Under these circumstances, the outlet valves are closed when a specific pedal travel, which corresponds to a specific degree of filling of the storage chamber, is exceeded. This is because, in order to maintain the operability of the anti-blocking system of the friction brake system, the storage chamber must not be entirely filled during regenerative deceleration.

Another advantageous mode of procedure consists in the fact that the storage chamber is completely filled during regenerative deceleration. If the anti-blocking system of the friction brake system comes into action when the storage chamber is full, a reduction in pressure can proceed only slowly, because of the full storage chamber. According to an embodiment of the invention, therefore, the driving motor or motors is/are switched briefly to drive via the control unit, in order to compensate for the excessive braking moment of the wheels.

The latter solution gains importance in combination with the choice of the strength of the spring in the storage chamber. When the outlet valves are open, the resistance to the pedal is determined by the spring in the storage chamber. This spring has hitherto been dimensioned so as to be as weak as possible, so that the braking pressure can be reduced to small values in the blocking situation. If, during the regenerative deceleration phase, the storage chamber spring represents the only resistance to the pedal, the spring may possibly have to be of somewhat stronger design in some exemplified embodiments. This means, however, that the braking pressure cannot be reduced to small values in the anti-blocking situation. In this case, too, the driving motors of the electric vehicle can be switched to drive, in order to compensate for the excessive braking moment of the friction braking. As an alternative to this, the hardness of the restoring springs at the pedal or in the main brake cylinder can be augmented, in order to increase the pedal counter-force during the regenerative deceleration phase.

If, for thermal reasons, the outlet valves used can be activated only for a short time, which is insufficient for the operational situation described, it is advantageous to activate the two outlet valves of a braking circuit alternately.

The embodiment of the invention which has been described is outlined in figure 4 with the aid of a flow chart. The appropriate computing programme is initiated when the brake pedal is actuated by the driver. In the first step 300, the evaluated operating quantities fed to the control unit, are read in. These are the desire to brake, the actual braking moment of the electric motor, and also other operating quantities such as the speed of the vehicle, the state of charge of the battery, etc. A check is thereupon carried out, in step 302, as to whether so-called "panic" braking is present. Panic braking of this kind is present, for example, if the speed of actuation of the brake pedal exceeds a predetermined limit value. In this event, according to step 304, no braking moment is predetermined for the electric motor, the friction braking installation is used in the conventional manner and a check is carried out, in the following interrogation step 306, as to whether at least one wheel is showing a tendency towards blocking. If this is the case, the ABS situation is present, in which the control unit illustrated in step 308 reduces the pressure, in accordance with known ABS algorithms, in the wheel which is showing a tendency towards blocking. Here, depending on the form of embodiment, the electric motor is, optionally, switched briefly to drive, in order to reduce the excess braking moment. After step 308, the part of the programme is repeated at the appropriate time, as long as actuation of the brake pedal continues, with step 300. If no panic braking has been identified in step 302, the ideal braking moment for the regenerative deceleration is determined, in step 310, on the basis of the desire to brake read in and also, optionally, of other operating quantities such as the state of charge of the battery, speed of the vehicle, etc. After that, a check is carried out, in the following step 312, as to whether the closing conditions for the outlet valves are fulfilled. That is to say, in the preferred exemplified embodiment, whether a predetermined pedal travel, which corresponds to a maximum degree of filling of the storage chamber, is exceeded. If this is the case, the outlet valves are not activated, or are no longer activated, and the procedure continues with step 306. If the closing condition is not fulfilled, the outlet valves are opened by timed activation in step 314. A check is thereupon carried out, in step 316, as to whether a reduction of the braking moment of the regenerative deceleration has taken place during the decelerating operation. If this is the case, the pump is started, and the switch-over valve optionally closed, as illustrated in step 318. After step 318, the procedure continues with step 306, as in the case of a "no" answer in step 316.

Figure 5 shows the braking moment of the motorised brake and of the hydraulic brake, recorded over the pedal travel. In a first range I, in which the outlet valves of the hydraulic brake are open, the braking moment is mainly applied on the basis of the motorised brake (curve 400) albeit with some contribution from the hydraulic braking system. The maximum motor moment is reached at a pedal travel SO. The hydraulic braking installation, then, is dimensioned in such a way that the storage chamber is full, or the maximum degree of filling of the storage chamber is reached, at the pedal travel SO, so that the outlet valves close. After that, in the region II, the braking moment is mainly applied by the hydraulic friction brake system. The curve 402 represents the cumulative curve from the braking moment contribution of the motorised and of the hydraulically actuatable friction brake system.

The mode of operation of this embodiment of the invention is further represented in figure 6 with the aid of time charts in the case of a typical braking situation. In this connection, figure 6a represents the pedal travel, figure 6b the braking moment applied by the electric motor, and figure 6c the braking moment applied by the friction brake system. At the point in time TO, the driver actuates the pedal to an extent that lies below the limit value SO. The braking moment is therefore applied almost solely by the electric drive with zero or negligible contribution from the friction brake system. The braking moment contribution of the friction braking is negligible. At the point in time T1, the driver actuates the brake pedal beyond the value SO. Since the electric braking moment has reached its maximum value at the point in time T1, from the point in time T1 onwards the braking moment is applied by the friction brake system in a manner corresponding to the pedal travel.

The device according to the invention may be used, not only in the hydraulic braking installations represented in figures 1 and 2, but in all braking installations in which the pressure fed into the brake line by the driver as a result of actuation of the brake pedal can be diverted into a storage element without leading to appreciable braking actuation.

The device of the invention may act not only on the driving wheels but on all the wheels of the braking installation.

CLAIMS

1. Device for controlling the braking installation of a vehicle with an electric drive, with at least one electric motor as the drive unit, with a friction brake system, with an electronic control unit which controls the brake, with a motor control unit which controls the electric motor, wherein the electronic control unit for the friction brake transmits an ideal braking moment for the regenerative deceleration of the vehicle to the motor control unit via the bus system, while the motor control unit transmits to the brake control unit the actual moment which has been set.

2. Device according to claim 1, wherein a measuring arrangement is provided for detecting actuation of the pedal, and the electronic brake control unit is designed in such a way that, in a first range of pedal actuation, the deceleration is applied almost exclusively by the regenerative deceleration, while the braking pressure built up in the friction brake as a result of actuation of the brake pedal produces, through appropriate control of the friction brake in this first range, no appreciable braking action in the friction brake, at least at the driving wheels of the vehicle.

3. A device for controlling the braking installation of a vehicle with electric drive substantially as herein before described with reference to the accompanying drawings.

The Patent Office

iLt

Application No:	GB 9817376.8	**Examiner:**	Peter Squire
Claims searched:	1 and 2	**Date of search:**	14 September 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): F2F FBB

Int Cl (Ed.6): B60T 13/58 B60L 7/24, 26

Other: Online:WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0361708 A2	(Ford) see Fig.2	1
X	US 5423600	(General Motors) see Fig.1	1
X	US 4671577	(Urban Transportation) see col.3 lines 25-36	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.