(12) UK Patent Application (19) GB (11) 2 217 413 (13) A

(43) Date of A publication 25.10.1989

(21) Application No 8908401.6

(22) Date of filing 13.04.1989

(30) Priority data
(31) 3812830 (32) 16.04.1988 (33) DE

(51) INT CL⁴
B60T 8/48

(52) UK CL (Edition J)
F2F FC FFE F611 F66X F686

(56) Documents cited
None

(58) Field of search
UK CL (Edition J) F2F FFE
INT CL⁴ B60T

(71) Applicant
Daimler Benz Aktiengesellschaft

(Incorporated in the Federal Republic of Germany)

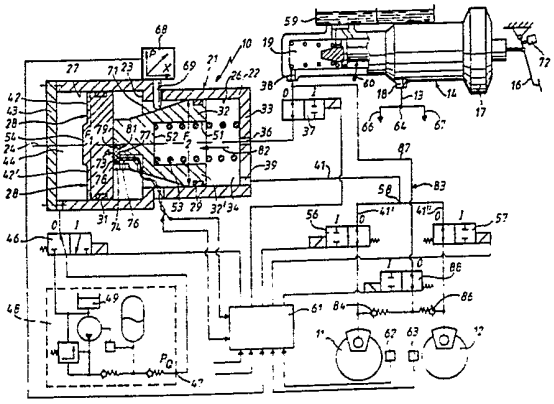
Stuttgart-Unterturkheim, Federal Republic of Germany

(72) Inventors
Heinz Leiber
Manfred Steiner

(74) Agent and/or Address for Service
Jensen & Son
8 Fulwood Place, High Holborn, London, WC1V 6HG
United Kingdom

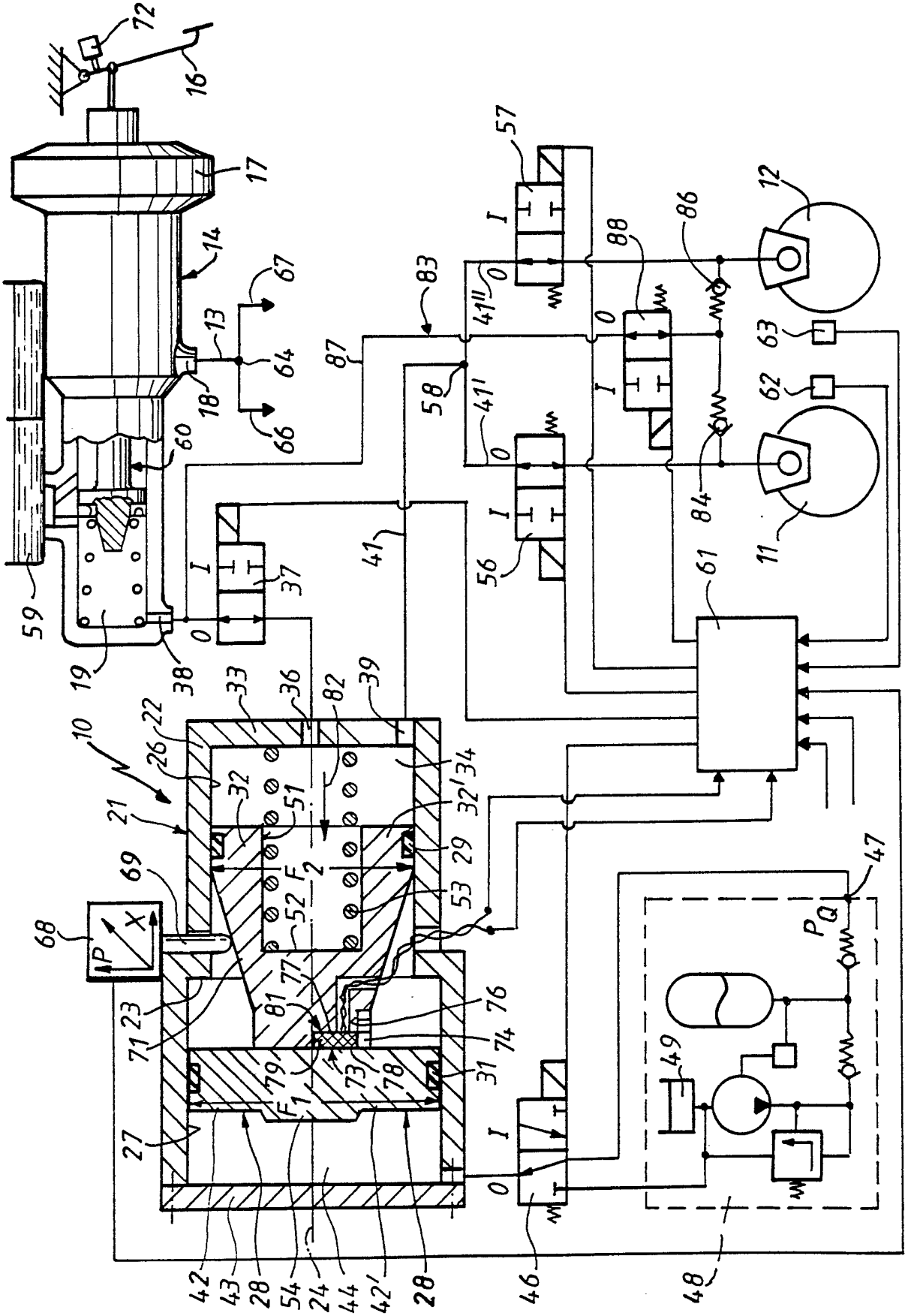
(54) Brake pressure modulating device

(57) In a brake pressure modulating device suitable for both an antilocking control system and a drive slip control system, a pressure modulator 21 designed as a stepped cylinder is provided, having a modulation chamber 34 connected to the main brake pipe 41 of the brake circuit II of the driven vehicle wheels and a control pressure space 44 separated from the modulation chamber 34 by the modulator piston 28, it being possible to connect the control pressure space 44 to the pressure outlet 47 of an auxiliary pressure source 48 and alternatively to its non-pressurised tank 49. A return spring 53 forces the piston 28 into its position associated with maximum volume of the modulation chamber. Connecting the control pressure space to the pressure outlet 47 moves the modulator piston 28 into the other end position provided for normal brake operation and suitable as the initial position for antilocking control system operation. If a spin tendency appears on a driven vehicle wheel, at a first threshold of slop or wheel acceleration the modulator piston 28 is brought - as a preparatory measure into its end position associated with maximum volume of the modulation chamber 34 so that brake fluid flows from the brake pressure generating unit 14 into the modulation chamber. In order to activate the drive slip control system at a second threshold, the modulation chamber is shut off from the unit 14 and the control pressure space is connected to the high pressure outlet of the auxiliary pressure source. The selection of the wheel to be subjected to the control is made by means of the brake pressure control valves provided for the antilocking control system.



GB 2 217 413 A

1/1


72
16
17
14
67
13
64
18
66
60
59
19
38
37
41
33
36
82
39
22
26
10
21
32
51
34
32'
29
53
52
F2
69
68
P
X
23
71
77
81
76
74
79
73
78
31
F1
27
42
43
28
54
24
44
42'
28
57
I
0
41''
88
86
12
83
87
58
41'
63
62
84
11
56
61
46
48
47
PQ
49

2217413

Brake pressure setting device

The invention concerns a brake pressure setting device by means of which, in control phases of a control device, e.g. an antilocking system, stabilising the dynamic behaviour of a road vehicle by action upon its brake installation, brake pressure build-up, brake pressure retention and brake pressure reduction phases can be automatically controlled in an order and combination to suit the situation.

Such a brake pressure setting device is, in association with an antilocking system for a road vehicle, the subject matter of the applicant's own, older, Patent Application P 3,723,875.2-21.

The antilocking system described in that application is intended for a road vehicle with front axle/rear axle brake circuit subdivision and rear axle drive. The static brake circuit associated with the driven rear wheels is connected to an outlet pressure space of a brake unit, designed as a tandem main cylinder of conventional construction type, via a pressure modulator and an inlet valve which can be triggered electrically. The pressure modulator is designed as a stepped cylinder with two bore steps of different diameters mutually offset by means of a housing step. A stepped piston with two flanges of correspondingly different diameters is guided in the stepped bores so that it is displaceable and pressure-tight, the two flanges forming the axially movable boundaries of a modulation chamber and a control pressure space respectively, whose boundaries fixed relative to the housing are each formed by an end wall of the cylinder housing. In this connection the modulation chamber is bounded by the smaller diameter piston step and is permanently connected to the initial section, branching off towards the wheel brakes, of the main brake pipe of the rear axle brake circuit. In addition, the modulation

chamber is connected by means of the inlet valve - in its basic position - to the brake unit secondary outlet pressure space associated with the rear axle brake circuit. The modulator piston is forced by a powerful return spring into the basic position associated with minimum volume of the modulation chamber. The control pressure space bounded by the larger piston step can be alternatively connected by means of an electrically drivable function control valve to the pressure outlet or the non-pressurised tank of an auxiliary pressure source, whereby the stepped piston is displaceable - against the force of the return spring and the pressure present in the modulation chamber - as far as its end position corresponding to the minimum volume of the modulation chamber and to the maximum volume of the modulation chamber.

Individually electrically controllable brake pressure control valves are associated with the wheel brakes and these valves can be driven, individually or jointly, from a basic position causing the connection between the particular wheel brake(s) and the main brake pipe of the rear axle brake circuit, and permitting brake pressure build-up and brake pressure reduction phases, into an alternative shut-off position by means of which brake pressure retention phases can be achieved. An electronic control unit is provided which generates signals, as required by the control system, for triggering the brake pressure control valves, the function control valve and the inlet valve by processing output signals, characteristic of the motion behaviour of the vehicle wheels, of wheel rotational speed sensors individually associated with the vehicle wheels.

In the antilocking system described in Patent Application P 3,723,875.2-21, the modulation chamber of the pressure modulator forms, as it were, a variable volume section of the main brake pipe which, during "normal" braking operation, i.e. one not subject to an antilocking control system, is kept at the minimum value of its volume and, in the case of a braking operation subject to the

control system, can be extended so that brake fluid can flow back into the modulation chamber from one of the wheel brakes subject to the control system, so that a reduction in brake pressure necessary for the antilocking control system is achieved in the wheel brake subject to the control system. Brake pressure restoration phases are controlled by the modulator piston being displaced back in the direction of its position corresponding to minimum volume of the modulation chamber.

Patent Application P 3,723,875.2-21 does not reveal any sort of measures by which the brake pressure setting device described therein could also be used for a drive slip control system operating on the principle of retarding a vehicle wheel tending to spin by activating its wheel brake again to such an extent that a stable dynamic behaviour of the vehicle is achieved even during acceleration operation.

Such a drive slip control system could, however, be effected in combination with the corresponding antilocking system in the patent application mentioned by providing a second pressure modulator for the brake circuit of the driven vehicle wheels. By means of this second pressure modulator - by connecting the outlet pressure of an auxiliary pressure source to a control pressure space of this pressure modulator and shutting off its outlet pressure space from the main brake cylinder - brake pressure can be built up in a wheel brake of a vehicle wheel which shows a tendency to spin which can be "selected" by means of the brake pressure control valve of the antilocking system.

Achieving a drive slip control system combined with an antilocking system in such a way would, however, be associated with substantial additional technical expenditure because, as well as the additional pressure modulator, further valves which could be triggered electrically would be necessary.

The same applies - in an analogous manner - to the combination of an antilocking system and a drive slip

control system described in German Offenlegungsschrift DE 3,706,661 A1, which is not a prior publication. In this combination, each of the vehicle wheels subject to an antilocking control system has, associated with it, its own pressure modulator, for each of whose functional controls a functional control valve designed as a 3/3-way solenoid valve is provided, and in which a further pressure modulator and a drive slip control valve are necessary to achive the drive slip function, by means of which latter control valve the connection or shutting-off of a control pressure space of this pressure modulator to or from the outlet of an auxiliary pressure source are controllable, the connection of which auxiliary pressure source to a control pressure space of the further pressure modulator making it possible to generate a pressure in the outlet pressure space which can be used as the brake pressure for the drive slip control. This pressure can be connected via inlet valves to the pressure modulators which can be used for antilocking control, these pressure modulators also being used for antilocking control.

German Patent DE 3,531,157 C1 also reveals - for a vehicle with all-wheel drive - a device for both antilocking control and drive slip control in which, again, each of the wheel brakes which can be used for one of the two types of control is associated with its own pressure modulator. In these pressure modulators, the inlet pressure space, which is connected to a pressure outlet of the brake unit, is sealed by the modulator piston against an outlet pressure space to which is connected the particular associated wheel brake by means of one solenoid valve each. For the antilocking control, a first drive pressure space is provided which can be connected by means of an antilocking control valve to an auxiliary pressure source. The application of pressure to the drive pressure space causes the modulator piston to be displaced - against the pressure generated by means of the brake unit and connected to the control pressure space in the direction of increasing the outlet pressure space connected to the wheel

brake. For the antilocking control, a second drive pressure space is provided as part of each of the modulators, it being possible to connect this second drive pressure space to the auxiliary pressure source or to shut it off from it by means of a drive slip control valve designed as a solenoid valve. Subjecting this second drive pressure space to pressure causes the modulator piston to experience a displacement in the direction of a build-up of brake pressure in its outlet pressure space, this permitting activation of the connected wheel brake, as necessary for a drive slip control without actuation of the brake unit. The inlet, outlet and drive pressure spaces, explained up to now, of the pressure modulators of the known antilocking and drive slip systems are located adjacent to one another within the particular modulator housing, viewed along the central longitudinal axis of the latter. This leads to a very "long" structural shape of the pressure modulators and to a corresponding disadvantage with respect to the installation volume required. The mechanical construction of the pressure modulators is complicated, on account of the numerous functional spaces, with respect to the design of both the modulator housing and the modulator piston and is associated with high technical expenditure.

In addition, very high actuation forces are necessary in the case of a failure of the braking force amplifier of the brake installation because the frictional resistances of numerous pressure modulator piston seals then have to be overcome by the pedal force with which the driver actuates the brake unit (which is all that is still available) "before" any worthwhile build-up of brake pressure can occur in the wheel brakes.

On the basis of a brake pressure setting device of the type mentioned at the beginning, it is therefore the object of the invention to improve this brake pressure setting device in such a way that it can be used for both the antilocking system and a drive slip control system operation - without any noticeable extra technical

expenditure.

According to the present invention there is provided a brake pressure setting device by means of which, in control phases of a control device stabilising the dynamic behaviour of a road vehicle by action upon its brake installation, brake pressure build-up, brake pressure retention and brake pressure reduction phases can be controlled, wherein

a) the wheel brakes of two driven vehicle wheels at least are combined in a static brake circuit, which

b) is connected via a pressure modulator and an electrically drivable inlet valve to an outlet pressure space of a brake unit,

c) the pressure modulator is designed as a stepped cylinder with two bore steps of different diameters in which a stepped piston, with two flanges of correspondingly different diameters, is guided so that it can be displaced in a pressure-tight manner, these flanges forming the axially movable boundaries of a modulation chamber and a control pressure space,

d) the modulation chamber is bounded by the smaller diameter piston step and is connected, on the one hand, via the pressure inlet control valve - in its basic position - to the outlet pressure space of the brake unit and, on the other hand, is permanently connected to the section of the main brake pipe, of the static brake circuit, branching off to the wheel brakes,

e) the pressure modulator is provided with a return spring which forces the modulator piston into its basic position associated with maximum volume of the modulation chamber,

f) the control pressure space bounded by the larger piston step can be alternatively connected, by means of an electrically drivable function control valve, to the pressure outlet or the non-

pressurised container of an auxiliary pressure source, whereby the stepped piston is displaceable - against the force of the return spring and the pressure present in the modulation chamber - as far as its end positions corresponding to the minimum volume of the modulation chamber and to the maximum volume of the modulation chamber,

g) electrically controllable brake pressure control valves individually associated with the wheel brakes are provided which can be driven individually or jointly from a basic position causing the connection between the particular wheel brake and the main brake pipe and permitting brake pressure build-up and pressure reduction phases into an alternative shutoff position which is associated with the brake pressure retention phases and

h) an electronic control unit is provided which generates signals, as required by the control system, for triggering the brake pressure control valves, the function control valve and the inlet control valve by processing output signals, characteristic of the motion behaviour of the vehicle wheels, of wheel rotational speed sensors, and wherein:

i) when a spin tendency appears on one of the driven vehicle wheels, the electronic control unit generates output signals by means of which the brake pressure control valves of the driven vehicle wheels are driven into their shut-off position (I) and the function control valve into its function positions causing pressure relief of the control pressure space of the pressure modulator, this occurring when the lower limiting values $\lambda_A 1$ and/or $b_A 1$ of the drive slip λ_A and/or the wheel peripheral acceleration b_A are exceeded, these lower limiting values being lower than the threshold values ($\lambda_A 2$ and/or $b_A 2$) beyond which the

use of a drive slip control system becomes necessary;

j) at the latest when the - higher - response threshold values $\lambda_A 2$ and/or $b_A 2$ are reached, the electronic control unit generates an output signal for switching the pressure inlet control valve into its shut-off position and an output signal which initiates the switching back into its basic position of that brake pressure control valve which is associated with the wheel with the tendency to spin and a signal which initiates the switching back of the function control valve into its basic position (0) causing the control pressure space to be connected to the pressure outlet of the auxiliary pressure source;

k) after the spin tendency has decayed, the electronic control unit generates that combination of its output signals which causes the switching back into their basic positions (0) of all the valves which can be electrically triggered.

By this means, the electronic control unit is, as it were, "extended" by a drive slip control function part which controls the following functions.

When a spin tendency appears on one of the driven vehicle wheels, which is "recognised" by monitoring the drive slip λ_A and the wheel peripheral accelerations b_A, output signals are generated by the electronic control unit even before relevant response threshold values $\lambda_A S$ and/or $b_A S$ are reached which, if they are exceeded, demand activation of the wheel brake of the vehicle wheel tending to spin, i.e. response from the drive slip control system. By means of these output signals, the brake pressure control valves of the driven vehicle wheels are driven into their shut-off position and the function control valve is driven into its function positions causing pressure relief of the control pressure space of the pressure modulator. By this means, the modulator piston experiences - due to the effect of its return spring - a displacement

in the direction of increasing the volume of the modulation chamber, into which brake fluid can flow from the outlet pressure space of the brake unit via the inlet valve which is still in its basic position, brake fluid flowing in turn from the reservoir of the brake installation into the outlet pressure space of the brake unit. As soon as the modulation chamber has accepted a quantity of brake fluid whose displacement into the brake circuit of the driven vehicle wheels can generate a sufficiently high brake pressure for the braking of these vehicle wheels, the inlet valve connected between the modulation chamber and the outlet pressure space of the brake unit is switched into its shut-off position - again by an output signal of the electronic control unit.

The brake pressure setting device is now, as it were, prepared for drive slip control operation whose introductory brake pressure build-up phase on a vehicle wheel tending to spin is/are then controlled, as soon as the drive slip and/or wheel acceleration of this wheel exceed the response theshold value $\lambda_A S$ and/or $b_A S$, by switching the brake pressure control valve of this vehicle wheel back again into its basic position - the through-flow position - and by also switching the function control valve back into its basic position, in which the control pressure space of the pressure modulator is again connected to the high pressure outlet of the auxiliary pressure source and, in consequence, the modulator piston experiences a displacement in the direction of reducing the volume of the modulation chamber, whereby brake fluid is forced into the wheel brake of the vehicle wheel subject to the control system and brake pressure is built up in this wheel brake to retard this vehicle wheel. A brake pressure retention phase on the vehicle wheel subject to the control system can be controlled by again switching its brake pressure control valve into its shut-off position.

In order to control brake pressure reduction phases of the drive slip control system, it is particularly advantageous if, as provided in Claim 2, the electronic

control unit first generates an output signal by which the function control valve is driven back into its actuated position I causing pressure relief of the control pressure space of the pressure modulator so that, initially, brake fluid is again accepted by the modulation chamber of the pressure modulator from the wheel brake of the vehicle wheel subject to the control system and the inlet valve is only subsequently switched back into its basic position connecting the modulation chamber with the outlet pressure space of the brake unit. By this means, the appearance of "pressure shocks" in the brake unit, which can lead to undesirable loads on the piston seals forming the boundaries of the outlet pressure space, can be substantially reduced.

In any event, all the valves are switched back into their basic position after the decay of the spin tendency in order to terminate the drive slip control.

The preparation of the brake pressure setting device for drive slip control operation, provided in Claim 3, has the advantage that the brake fluid in the modulation chamber and the main brake pipe of the brake circuit of the driven vehicle wheels connected to it is already under high pressure when the brake pressure control valve of the wheel brake of the vehicle wheel to be subjected to the control system - for the purpose of brake pressure build-up - is switched back again into its basic position. This is of benefit to a rapid response of the drive slip control.

In a preferred arrangement of the brake pressure setting device according to the invention, the pressure modulator is provided with a position indicator which is adapted to generate an electrical output signal characteristic of the position of the piston of the pressure modulator.

By means of such a displacement indicator, it is, for example, possible to direct - very accurately - a withdrawal motion of the modulator piston, which causes the brake pressure reduction in a wheel brake, to that position from which, when the pressure build-up phase commences, the

displacement of the modulator piston took place in the direction of a build-up of brake pressure. This makes it possible to reduce to a minimum or, in principle, even to avoid balance flows between the brake unit and the modulation chamber, which might otherwise occur when the inlet valve is opened - with the object of avoiding pressure shocks in the brake unit. In addition, the output signals of such a displacement indicator can also be used in an advantageous manner for both the drive slip control operation and the antilocking control operation in order to achieve control, to meet the requirements, of the apportionment and/or reduction of pressure, an improvement in the control behaviour for both types of control being achievable in an obvious manner.

The same applies in an analogous manner to a further preferred arrangement in which the modulator piston is provided with a force sensor which generates an electrical output signal characteristic of the pressure in the modulation chamber. The - electrical - output signal of this signal generator is a direct measure of the brake pressure in the wheel brake subject to the control system and can therefore also be used for correct brake pressure control to suit the control requirements.

Although the brake pressure setting device is fail-safe to such an extent that, should the electronic control fail, the inlet valve, the brake pressure control valves and the function control valve return to their basic positions, in which normal brake operation is possible, it may nevertheless be expedient if, as an additional safety measure, a bypass flow path is provided "in parallel" to the brake pressure setting device, designed according to Claim 6 for example, by means of which, should the inlet valve "stick" in its shut-off position after an antilocking or a drive slip control phase, at least the brake pressure can be reduced again by withdrawal of the brake pedal.

Further details and features of the invention are given by the following description, of a particular illustrative example, using the drawing which shows, in a

simplified diagrammatic block circuit diagram presentation, an antilocking system and drive slip control system brake pressure setting device according to the invention designed for a road vehicle with front axle/rear axle brake circuit subdivision and rear axle drive.

In the drawing, to whose details attention is expressly drawn, elements essential to the function of the hydraulic two-circuit brake installation of a road vehicle are also shown to explain a brake pressure setting device, indicated overall by 10, which vehicle is equipped with both an antilocking system and a drive slip control system, the brake pressure setting device - according to the invention - being provided both for controlling brake pressure reduction, retention and restoration phases of the antilocking system and for control of brake pressure build-up, retention and brake pressure reduction phases of the drive slip control system. Without limitation of generality, it is assumed that the vehicle has a rear axle drive, the rear wheel brakes 11 and 12 representing the driven vehicle wheels being combined in a rear axle brake circuit II and, correspondingly, the front wheel brakes, not shown for simplicity, are combined in a front axle brake circuit I which is only represented in the drawing by the main brake pipe 13 branching off to the front wheel brakes. The two brake circuits I and II are assumed to be static brake circuits for whose brake pressure supply a stepped tandem main cylinder 14 of a construction type known per se is provided in the particular illustrative example shown. This tandem main cylinder can be activated by means of the brake pedal 16 via a brake force amplifier 17, e.g. a vacuum brake force amplifier, the front axle brake circuit I being connected to the pressure outlet 18 of the primary stage of the tandem main cylinder 14 and the rear axle brake circuit II being connected to the outlet pressure space 19 of the secondary stage of the tandem main cylinder 14.

The brake pressure setting device 10 provided for the brake pressure control corresponding to the particular

control purpose in the rear axle brake circuit II includes, as a central functional element, a pressure modulator designed as a stepped cylinder, indicated overall by 21, whose casing 22 has two bore steps 26 and 27 arranged adjacent to one another in the longitudinal direction of the modulator housing 22, co-axial with respect to its central longitudinal axis 24 and mutually offset and joining one another by means of a radial step 23. A correspondingly stepped modulator piston, indicated overall by 28, is sealed against the bore steps 26 and 27 by ring seals 29 and 31, respectively, fixed relative to the piston, the modulator piston being displaceable in total.

A functional space of the pressure modulator 21, referred to below as the modulation chamber 34, is movably bounded in the axial direction by the smaller diameter piston flange 32 of the modulator piston 28 within the smaller bore step 26 of the modulator housing 22 and has a boundary fixed relative to the housing by an end wall 33 of the modulator housing 22 closing the bore step 26 from the outside. Brake pressure reduction and brake pressure build-up phases of the control types to be considered can be controlled by the - controllable changes in volume of this modulation chamber 34.

This modulation chamber 34 has a pressure inlet 36 which is connected to the secondary pressure outlet 38, of the tandem main cylinder 14, associated with the rear axle brake circuit II via a pressure inlet control valve 37, which in the particular illustrative example shown is designed as a 2/2-way solenoid valve whose basic position 0 is its through-flow position and whose actuated position I is its shut-off position; in addition, the modulation chamber 34 has a pressure outlet 39 to which is connected the main brake pipe 41, of the rear axle brake circuit II, branching off towards the rear wheel brakes 11 and 12.

Another functional space of the pressure modulator, referred to in what follows as the control pressure space 44, is bounded in the axial direction by the larger diameter annular flange-shaped piston step 42 of the

modulator piston 28 and the end wall 43 of the modulator housing 22 closing towards the outside the- correspondingly larger - bore step 27 of the modulator housing 22, against which larger step this larger piston step 42 is sealed so that it can be displaced. The control pressure space 44 can be connected via a function control valve 46 - alternatively - to a pressure outlet 47, held at a high pressure level - of a hydraulic auxiliary pressure source, indicated in total by 48, and can by this means be subject to its outlet pressure and can be relieved to its- non-pressurised - container 49.

In the particular illustrative example shown, this function control valve 46 is designed as a 3/2-way solenoid valve in whose basic position 0 the control pressure space 44 of the pressure modulator 21 is connected to the pressure outlet 47 of the auxiliary pressure source but is shut off from its container 49 and, in its actuated position I, the control pressure space 44 of the pressure modulator 21 is connected to the container 49 of the auxiliary pressure source 48 but is shut off from its pressure outlet 47.

On the smaller piston step 32 of the modulator piston 28, a central blind hole 51 open towards the modulation chamber 34 is provided whose - axial - depth corresponds approximately to the length of this smaller piston step 32.

A powerful return spring 53 is axially supported on the bottom 52 of this blind hole 51 of the modulator piston 28, on the one hand, and on the end wall 33 closing the smaller bore step 26 of the modulator housing 22 towards the outside. This return spring 53 attempts to force the modulator piston 28 into its end position, on the left in the drawing, associated with maximum volume of the modulation chamber 34 and, at the same time, minimum volume of the control pressure space 44. In this end position, the modulator piston 28 is supported by means of a central stop protrusion 54, only slightly extended in the axial direction, against the end wall 43 of the modulator housing

22 closing the larger bore step 27 from the outside.

The other end position of its modulator piston 28 associated with minimum volume of the modulation chamber 34 and, at the same time, maximum volume of the control pressure space 44 of the pressure modulator 21 is the one which is indicated by contact between its larger piston step 42 and the radial housing step 23.

The brake pressure control valves 56 and 57 also provided as part of the brake pressure setting device 10, by means of which the brake pipe branches 41' and 41", starting from the branch position 58 of the main brake pipe 41 of the rear axle brake circuit II and leading to the wheel brakes 11 and 12, can be shut off singly or at times - jointly from the pressure outlet 39 of the modulation chamber 34 of the pressure modulator 24, are in the particular illustrative example shown - designed as 2/2-way solenoid valves, each of whose basic positions 0 is the through-flow position and each of whose actuated positions I is the shut-off position.

Before dealing below with further constructional details of the brake pressure setting device 10, in particular its pressure modulator 21 and their function, consideration is first given to how the brake pressure change and brake pressure generation phases necessary for both antilocking control and for drive slip control can be achieved using the functional components, described up to now, of the brake pressure setting device 10 at the wheel brakes 11 and 12 of the driven vehicle wheels. It is assumed that the antilocking control and the drive slip control each take place in accordance with in this connection generally known criteria and that, therefore, it is unnecessary to explain them.

In order to explain typical antilocking and drive slip control cycles which can be controlled by means of the brake pressure setting device 10, the antilocking control operation is considered first.

As long as the antilocking control system has not responded, the pressure inlet control valve 37, the

function control valve 46 and the brake pressure control valves 56 and 57 each adopt their basic position 0, as shown. The piston 28 of the pressure modulator 21 is subjected on its cross-sectional area F_1 corresponding to the cross-sectional area of the larger bore step 27 of its housing 22 to the - high - outlet pressure P_Q of the auxiliary pressure source 48, which is connected to the control pressure space 44 of the pressure modulator 21 via the function control valve 46 which is in its basic position 0. On its area F_2 of the smaller piston step 32 corresponding to the cross-sectional area of the smaller bore step 26 of the modulator housing 22, the modulator piston 28 is subjected - when the brake installation is actuated - to the brake pressure P_B generated by the brake unit 14 and connected to the modulation chamber 34 via the pressure inlet control valve 37, which is in its basic position 0. The brake pressure is also connected to the wheel brakes 11 and 12 of the driven rear wheels of the vehicle via the main brake pipe 41, of the rear axle brake circuit II, connected to the pressure outlet 39 of the modulation chamber 34, and the wheel brake pipe branches 41' and 41", which pass via the brake pressure control valves 56 and 57.

The ratio F_1/F_2 of the effective areas F_1 and F_2 of the larger piston step 42 and the smaller piston step 32 of the modulator piston 28 is selected to be sufficiently large so that even if the maximum brake pressure P_B which can be achieved by actuating the brake unit 44 is connected to the modulation chamber 34, the modulator piston 28 is pushed into its end position associated with minimum volume of the modulation chamber 34 because the larger piston step 42 is subject to the outlet pressure P_Q of the auxiliary pressure source 48 against the return force of the return spring 53 - and can be held in this position, remaining there as long as the control pressure space 44 is connected to the pressure outlet 47 of the auxiliary pressure source 48.

It should be noted at this point that the modulator

piston 28, notwithstanding the representation of the solenoid valves 37, 46, 56 and 57 in their basic positions 0, is not in the end position corresponding to the minimum volume of the modulation chamber 34 but is shown in an intermediate position to which reference will be made later in order to explain a control cycle of the drive slip control system.

If a locking tendency occurs during a braking operation, e.g. on the left-hand rear wheel represented by the wheel brake 11, an introductory brake pressure reduction phase of an antilocking control cycle necessary in this situation is controlled as follows:

The pressure inlet control valve 37 connected between the pressure outlet 38 and the pressure inlet 36 of the modulation chamber 34 of the pressure modulator 21 is driven into its actuated position I - the shut-off position; by this means, further build up of brake pressure in the rear axle brake circuit II is no longer possible even if the driver continues to actuate the brake pedal 16 with increasing foot force.

Switching the pressure inlet control valve 37 into its shut-off position I also initiates the switching of the brake pressure control valve 57, associated with the wheel brake 12 of the right-hand rear wheel, into its shut-off position I and this has the effect that in the wheel brake 12 of the right-hand rear wheel, which can still transmit braking force, the brake pressure is retained at the value selected before activation of the antilocking control system.

Furthermore, switching the pressure inlet control valve 37 into its shut-off position I also initiates the switching of the function control valve 46 into its actuated position I in which the control pressure space 44 of the pressure modulator 21 is now connected to the non-pressurised container 49 of the auxiliary pressure source 48 and can be relieved into this tank. The brake pressure control valve 56 associated with the left-hand rear wheel brake 11, on which the brake pressure has to be reduced,

remains in its basic position 0 - the throughflow position.

The pressure reduction occurs because the modulator piston 28 experiences a displacement in the direction of increasing the volume of the modulation chamber 34 due to the return spring 53 and the pressure present in the modulation chamber 34 because the pressure in the control pressure space 44 has now been relieved so that brake fluid can flow via the main brake pipe 41 of the rear axle brake circuit II into the modulation chamber 34 and, in consequence, a brake pressure reduction is also achieved in the left-hand rear wheel brake 11.

Pressure reduction phases can also be controlled in an analogous manner on the right-hand rear wheel brake 12 and, if necessary, on both rear wheel brakes 11 and 12.

If, after a brake pressure reduction phase as described so far, the brake pressure on the wheel brake 11 has to be kept at the - lowered - value achieved up to this point by the control system, the brake pressure control valve 56 associated with the left-hand rear wheel brake 11 is also driven into its shut-off position I while the pressure inlet control valve 37 continues to be held in its shut-off position and while the function control valve 46 is now switched back into its basic position 0 so that the outlet pressure P_Q of the auxiliary pressure source 48 is again connected to the control pressure space 44 of the pressure modulator 21. Displacement of the modulator piston 28 in the direction of reducing the volume of its modulation chamber 34 does not, however, occur because the modulation chamber 34 remains - initially - shut off from both the pressure outlet 38 of the tandem main cylinder 14 and from the wheel brakes 11 and 12.

For a subsequently necessary brake pressure restoration phase on one or both rear wheel brake(s) 11 and/ or 12, the brake pressure control valve 56 and/or 57 of the particular rear wheel brake 11 and/or 12 is switched back into its basic position 0 while the pressure inlet control valve 37 connected between the pressure modulator 21 and the brake unit 14 continues to be kept in its shut-

off position I.

Because the outlet pressure P_Q of the auxiliary pressure source 48 is now again connected to the control pressure space 44 of the pressure modulator 21, the modulator piston 28 now experiences a displacement in the direction of reducing its modulation chamber 34. By this means, brake fluid which had previously been accepted by the modulation chamber 34 from the wheel brake(s) 11 and/or 12 subject to the control system so as to reduce the brake pressure is now forced back again into the wheel brake(s) 11 and/or 12 - so as to restore brake pressure.

If, after a brake pressure restoration phase of the antilocking control system controlled in the manner described above, there is no longer any locking tendency on the rear axle of the vehicle, the pressure inlet control valve 37 connected "between" the brake unit 14 and the pressure modulator 21 is also switched back into its basic position 0 so that the outlet pressure P_B of the tandem main cylinder 14 is now again available for a further build-up of brake pressure.

If, on the other hand, a spin tendency appears on one of the driven vehicle wheels (the left-hand rear wheel of the vehicle for example) which has to be combated in order to ensure the dynamic stability of the vehicle, an action on the brake suitable for this purpose can be controlled as follows:

If a spin tendency, which is initially still "weak", appears on one of the driven vehicle wheels, e.g. the left-hand rear wheel, such that the drive slip λ_A of the rear wheel considered exceeds a first threshold value λ_{A1} which is, however, still within the range of values compatible with good driving stability (this range of values being limited by an upper boundary λ_{A2} beyond which activation of the drive slip control is necessary) and/or a threshold value b_{A1} of the wheel peripheral acceleration is exceeded which again is still within the range of acceleration values compatible with good driving stability (this range of values being again limited by an upper

boundary b_A2 beyond which activation of the drive slip control system becomes necessary), these threshold values λ_A1 and b_A1 differing only relatively "slightly" from the particular upper boundaries λ_A2 and b_A2, e.g. by 20-30% of the magnitude of these boundaries from the upper limiting values λ_A2 and b_A2, the brake pressure setting device 10 is then prepared - prophylactically as it were - for drive slip control operation. This is done by switching the two brake pressure control valves 56 and 57 into their shut-off positions I and also switching the function control valve 46 into its actuated position I. The rear wheel brakes 11 and 12 are therefore shut off from the modulation chamber 34 of the pressure modulator 21 which, however, is connected, via the still open pressure inlet control valve 37, to the secondary outlet pressure space 19 of the tandem main cylinder 14 and therefore also to its brake fluid reservoir 59. The control pressure space 44 is now relieved to the tank 49 of the auxiliary pressure source 48 via the function control valve 46 with the result that the modulator piston 28 - due to the action of the return spring 53 -experiences a displacement in the direction of increasing the volume of the modulation chamber 34. A quantity of brake fluid corresponding to the increase in volume flows, via the pressure inlet control valve 37 which is in its basic position 0, from the secondary outlet pressure space 19 of the tandem main cylinder 14 into the modulation chamber 34 of the pressure modulator 21, a corresponding quantity of brake fluid flowing from the brake fluid reservoir 59 into the secondary outlet pressure space 19 of the tandem main cylinder 14, which is possible in the basic position of the floating piston 60, of the tandem main cylinder 14, forming the movable boundary of the secondary outlet pressure space 19, this basic position corresponding to the non-actuated condition of the brake installation.

It is first assumed that by this means, the modulator piston reaches its end position, on the left of the drawing, associated with maximum volume of the

modulation chamber 34.

The pressure inlet control valve 37 is then switched, again as a preparatory measure, into its shutoff position I. If the spin tendency of the left-hand rear wheel increases further in such a way that at least one of the two upper limiting values $\lambda_A 2$ and $b_A 2$ of the drive slip or of the wheel peripheral acceleration of the vehicle wheel considered is exceeded, the function control valve 46 and the brake pressure control valve 56 of the wheel brake 11 of the vehicle wheel tending to spin are again switched into their basic positions 0 so that, on the one hand, the control pressure space 44 is again subject to the high outlet pressure P_Q of the auxiliary pressure source 48, the modulator piston 21 experiences a displacement in the direction of reducing the volume of its modulation chamber 34 and brake fluid is forced into the wheel brake cylinder of the wheel brake 11 of the vehicle wheel tending to spin, which is braked by this means.

Thus, as soon as a reduction in the spin tendency, initially only in the sense that the drive slip λ_A, no longer increases and, in consequence, the magnitude of the wheel peripheral acceleration b_A has become 0, the brake pressure control valve 56 is again switched into its shut-off position I and, by this means, the brake pressure in the wheel brake 11 of the rear wheel possibly still subject to excessive drive slip λ_A is held at the value to which it has been controlled up till then.

If the spin tendency of the vehicle wheel considered does not decay further, which can, for example, be recognised from a renewed increase in the wheel peripheral acceleration b_A and/or of the drive slip λ_A, the brake pressure control valve 56 is again switched back into its basic position 0 - its through-flow position and the brake pressure in the wheel brake 11 is further increased.

If, after a subsequent second brake pressure retention phase, which can be controlled in a manner analogous to the above first brake pressure retention phase (or even after the earlier phase), the spin tendency of the

vehicle wheel considered decays, which is recognisable from the fact that the drive slip λ_A and the wheel peripheral acceleration b_A of the previously spinning vehicle wheel are again within the range of values of these parameters compatible with good driving stability, the drive slip control is ended by switching the brake pressure control valves 56 and 57 of the rear axle brake circuit II and also the brake inlet control valve 37 back into their respective basic positions 0, by which means the brake pressure connected to the wheel brake 11 of the vehicle wheel previously tending to spin is again completely reduced and the brake fluid quantity previously accepted by the modulation chamber 34 of the pressure modulator 21 is also forced back into the outlet pressure space 19 of the tandem main cylinder 14 or into its brake fluid reservoir 59.

During this procedure, it is desirable that the brake pressure control valve 57 of the wheel brake 12 of the right-hand rear wheel of the vehicle not previously tending to spin should be switched back into its basic position 0 only after the brake pressure in the wheel brake 11 of the rear wheel previously tending to spin has been completely reduced.

The brake pressure reduction phase concluding a control cycle of the drive slip control can also be controlled in such a manner that while the pressure inlet control valve 37 is initially still held in its shut-off position I, the function control valve 46 is switched into its actuated position I and, by this means, a displacement of the modulator piston 28 in the direction of increasing the volume of its modulation chamber 34 is first initiated in such a way that the quantity of brake fluid previously displaced into the main brake pipe 41 of the rear axle brake circuit II and into the wheel brake 11 of the vehicle wheel subject to the control system is initially re-accepted quantitatively by the modulation chamber 34, which again leads to a complete brake pressure reduction in the wheel brake 11 used for the control. After this, its brake pressure control valve 56 is switched back into its shut-

off position I, the brake pressure control valve 57 of the other rear wheel brake 12 also continuing to be held in its shut-off position I, and the pressure inlet control valve 37 is then switched back into its through-flow position 0, whereupon the function control valve 46 is switched back into its basic position 0 and, by this means, the displacement of the modulator piston 28 causing the brake fluid previously accepted in the modulation chamber 34 to be pumped back into the outlet pressure space 19 and the reservoir 59 of the tandem main cylinder 14 is achieved. The signals necessary for triggering, as required by a switching according to the control system of the pressure inlet control valve 37, the function control valve 46 and the brake pressure control valves 56 and 57 of the setting device 10 - as required by both the antilocking control system and the drive slip control system are generated by an electronic antilocking control and drive slip control unit, indicated only diagrammatically in the drawing, according to criteria assumed to be known and essentially by a process of comparing and differentiating the output signals of wheel rotational speed sensors 62 and 63, which are provided for monitoring the motion behaviour of the vehicle wheels and emit electrical output signals characteristic of their peripheral speeds. Such wheel rotational speed sensors are provided not only for the driven rear wheels of the vehicle, as shown in the drawing, but also for its non-driven front wheels.

"Various" control phases are possible on the two rear wheel brakes 11 and 12 with the brake pressure setting device 10 shown to the extent that the brake pressure can be increased or lowered on one wheel brake 11 or 12 while it is kept constant on the other rear wheel brake 12 or 11. By means of these feedback and open chain control possibilities, which are achieved with a favourably simple overall construction of the brake pressure setting device 10, a control behaviour fully adequate for practical requirements is achieved - on the rear axle of the vehicle - with respect to both antilocking control and drive slip

control. With respect to antilocking control, this control behaviour is, in fact, more sensitive than, for example, that of an antilocking control operating on the select-low principle and, with respect to the drive slip control, it fulfills to an adequate extent the requirements of a single-wheel control because it is always possible to have the control applied to the wheel which first tends to spin.

A "counterphase" brake pressure change on the two rear wheel brakes 11 and 12, in the sense that the brake pressure is increased on one wheel brake 11 or 12 and is simultaneously decreased on the other wheel brake 12 or 11, is not however possible with the brake pressure setting device shown.

A counterphase brake pressure control in this sense (which - in terms of antilocking control - is important on the front axle rather than the rear axle) can of course be achieved, however, assuming an analogous design of brake pressure setting devices provided for the front wheel brakes, provided a pressure modulator corresponding in its fundamental construction to the pressure modulator 21 shown in the drawing, a pressure inlet control valve and an antilocking functional control valve 46 are associated with each of the front axle brake circuit branches 66 and 67 emerging from the branch position 64 of the front axle brake circuit I and only shown diagrammatically, it being also possible to use the auxiliary pressure source 48 for the brake pressure setting device of the front axle brake circuit I.

The design of the brake pressure setting device 10 overall, necessary for the possibility of "counterphase" control of the brake pressure on the front wheel brakes and/or the rear wheel brakes 11 and 12 should a counterphase control be desired there, and the design of the electronic control unit 61 in that case necessary for control purposes are possible to the specialist, given knowledge of the control objective, on the basis of his assumed specialist knowledge so that explanations in this respect appear unnecessary.

The pressure modulator 21 of the brake pressure setting device 10, explained up to this point with respect to its fundamental construction and the consequently possible control functions, is equipped in its particular configuration shown with a displacement and position indicator 68 which generates an electrical output signal varying continually with deflections of the modulator piston 28 and characteristic of its current position. This output signal is supplied as additional information input to the electronic antilocking and drive slip control unit 61.

This displacement indicator 68, which can be designed in a construction type known per se, e.g. as a resistance signal generator or an inductive signal generator, records - in the particular illustrative example shown - the radial deflections of an actuation pin 69 associated with the axial displacements of the piston 28. The free end of the actuation pin 69 has sliding support on a conical outside surface 71 of the modulator piston 28. This surface extends between the piston flange 32 sealed against the smaller bore step 26 and the larger piston flange 42, of the modulator piston 28, sealed against the larger bore step 27 and, as may be seen from the drawing, becomes narrower towards the larger piston step 42. Here, the axial extent and arrangement of this conical outer surface 71 of the modulator piston 28 is arranged in such a way that the output signal of the displacement and position indicator 68 is correlated in an unambiguous manner with the piston position in each of the intermediate positions possible between the two end positions of the piston 28, the position indicator 68 being preferably so designed that its output signal varies in proportion to changes in the piston position.

In a particular design of the brake pressure setting device 10 and its electronic control unit 61, the modulator piston 28 is brought from its basic position corresponding to minimum volume of the modulation chamber 34 into the intermediate position shown in the drawing

whenever, during acceleration operation of the vehicle, the "sensitization" threshold values (sic) $_A1$ and/or b_A set for the recognition of an imminent spin tendency are exceeded. This intermediate position corresponds, for example, to half the value of the maximum volume of the modulation chamber 34 and also, correspondingly, to half the value of the maximum volume of the control pressure space 44. Occupation of the central position of the piston 28 can, for example, be controlled by the function control valve 46 being switched into its actuated position I associated with pressure relief of the drive pressure space 44, while the pressure inlet control valve 37 takes up its basic position 0, until the output signal of the position indicator 68 shows that the piston 28 has passed slightly "to the other side" of the central position, i.e. has reached a position corresponding to a volume somewhat larger than half the value of the maximum volume of the modulation chamber 34 and that the function control valve 46 is then switched back, pulsating if necessary, into its basic position or is switched between its actuated position I and the basic position 0 until the output signal of the position indicator 68 shows that the piston 28 has reached its intermediate position provided for the expected control operation, whereupon the pressure inlet control valve 37 is switched into its actuated position I - the shut-off position - and the function control valve 46 is -initially held in its basic position 0 connecting the control pressure space 44 with the pressure outlet 47 of the auxiliary pressure source 48. During this setting procedure, the brake pressure control valves 56 and 57 are, of course, switched into their shut-off positions I, as already explained above, and are also held in their shutoff positions I until a drive slip control phase is initiated or the vehicle is to be retarded by actuation of the brake installation.

The brake pressure setting device 10 is now prepared for both drive-slip control operation and antilocking control operation because it is possible to

displace the modulator piston 28 from its intermediate position, which has been assumed as a preparatory measure, in the direction of either a volume reduction or a volume increase of the modulation chamber 34 of the pressure modulator 21.

If, in the vehicle acceleration phase assumed as the driving situation, a spin tendency occurs on one of the driven vehicle wheels, the measures taken to combat it can be controlled as already explained above although, in the explanation example selected, a volume of brake fluid corresponding to only half the maximum volume of the modulation chamber 34 is initially available for the brake pressure build-up in the wheel brake(s) 11 and/or 12. If the quantity of brake fluid displaceable into the brake circuit II by one brake pressure build-up stroke of the modulator piston 28 is not sufficient for a build-up of brake pressure sufficient to combat the spin tendency in the wheel brake activated for control purposes, e.g. the left-hand rear wheel brake 11, the brake pressure control valve 56 of the rear wheel brake 11 subject to the control system is also switched back into its shutoff position I while the brake pressure control valve 57 of the right-hand rear wheel brake 12 continues to be held in its shut-off position I. The function control valve 46 is then switched into its actuated position I and the pressure inlet control valve 37 is switched back into its basic position 0 so that brake fluid can again flow into the modulation chamber 34, whose volume is increasing. This brake fluid can be used in a subsequent brake pressure build-up phase for a further build-up of brake pressure in the wheel brake 11 subject to the control system, this brake pressure build-up phase being controllable in a manner analogous to that already described above, i.e. by renewed switching of the function control valve 46 into its basic position 0 and by switching the pressure inlet control valve 37 into its actuated position I - its shut-off position - and switching back the brake pressure control valve 56 of the wheel brake 11 into its basic position 0.

The output signal of the position indicator 68 can then be used for control, to meet the requirements, of the displacement motions of the modulator piston 28 necessary for a further supply of brake fluid into the brake circuit II of the driven vehicle wheels. This occurs by the modulator piston 28 experiencing a displacement in the direction of increasing the modulation chamber 34 of the pressure modulator 21 only to the extent necessary to accept that volume of brake fluid which is still required to build up the "residual" brake pressure necessary to combat the spin tendency.

Information on the position of the modulator piston 28 provided by the position indicator 68 therefore makes it possible to minimise the periods necessary for the displacements, to suit the requirements, of the modulator piston 28 and hence to minimise the controlcycle times overall, thus improving the control sensitivity.

If, in the operating situation of the vehicle described in which its brake pressure setting device 10 was prepared for a drive-slip control operation, and it therefore has to be assumed, on the other hand, that the vehicle is in motion on a track with "poor" friction coefficients between the track and the vehicle wheels, there is braking, since braking must take priority over driveslip control, the pressure inlet control valve 37 and the brake pressure control valves 56 and 57 of the rear wheel brakes 11 and 12 are switched back into their basic positions so that brake pressure can be built up in these rear wheel brakes. This switching operation preferably does not take place until the outlet pressure space 19 of the tandem main cylinder 14 associated with the rear axle brake circuit II is shut off, after an introductory displacement of the main cylinder piston 60, from the brake fluid reservoir 59 in order to prevent brake fluid from flowing back from the pressure modulation chamber 34 of the pressure modulator 21 via the now open pressure inlet control valve 37 into the outlet pressure space 19 mentioned of the tandem main cylinder 14 and via the latter

to the brake fluid reservoir 59. An advantageous control possibility can also consist in the fact that when the brake installation is actuated, initiated for example by the output signal of the brake light switch 72, the signal being supplied as a further information input to the electronic control unit 61, the brake pressure control valves 56 and 57 are first switched back into their basic positions before the pressure inlet control valve 37 is switched back into its basic position in order, by this means, to build up brake pressure in the rear wheel brakes 11 and 12 by means of the pressure modulator 21 "in advance", "before" the pressure inlet control valve 37 is switched into its basic position 0. A braking action necessary in this situation will therefore be supported in an obvious manner by the brake pressure setting device 10 prepared for the drive slip control operation.

If a locking tendency appears on one of the rear wheels during the course of this braking operation, which will be the case with a relatively high degree of probability given the assumed initial situation, the brake pressure setting device 10 is also adequately prepared for the then necessary antilocking control operation because even if the antilocking control operation starts immediately, i.e. while the piston 28 is practically still in the central position shown, there is still sufficient displacement path available for an increase in volume of the modulation chamber 34. If, on the other hand, the antilocking control is only initiated "later", i.e. after a quantity of brake fluid has been displaced into the wheel brakes 11 and 12 whose volume is greater than the increase in volume of the modulation chamber 34 achievable by a single return stroke of the modulator piston 28, and if the antilocking control demands a very substantial reduction in brake pressure which cannot be provided by a single modulation stroke of the piston 28 leading to the end position associated with the maximum volume of the modulation chamber, the brake pressure setting device is then switched to "pump-back operation", as it were. For

this purpose, the two brake pressure control valves 56 and 57 of the rear axle brake circuit II are switched into their shut-off positions I and both the function control valve 46 and the pressure inlet control valve 37 are switched back into their basic positions 0 and, by this means, a pump-back stroke of the modulator piston 28 is initiated by means of which brake fluid previously accepted by the modulation chamber 34 in pressure reduction operation is pumped back into the secondary output pressure space 19 of the brake unit 14. Here again, the output signal of the position indicator 68 is used for stroke control of the modulator piston 28 in such a way that its pressure reduction and pump-back strokes, and hence the periods required for them, are minimised.

Using the modulator piston 28 intermediate position, which can be inspected by means of the position indicator 68, the brake pressure setting device 10 can therefore be prepared for a similarly good response behaviour with respect to both drive slip and antilocking operation.

The output signals of the position indicator 68 characteristic of the piston position can be used in many ways for both drive slip and antilocking operation for control, to suit the requirements, of brake pressure change phases. Only two representative examples are quoted by means of which the general principle of such possibilities of use can be recognised:

If, in the course of a brake pressure reduction phase of an antilocking control cycle, a slight displacement of the modulator piston 28 in the direction of increasing the modulation chamber 34 has already sufficed to terminate a locking tendency on the rear axle, the electronic control unit 61 assesses the relevant output signal of the position indicator 68 which, for this purpose, is compared with the position signal characteristic of the initial position of the piston 28 as, for example, indicating that the changes in the friction coefficients between the track and the braked vehicle wheel

initiating the response of the antilocking control system were obviously only relatively slight and that, in consequence, in a subsequent brake pressure restoration phase, the brake pressure can be "immediately", i.e. without insertion of a brake pressure retention phase, increased again to the value previously selected by means of the brake unit.

On the other hand, if - whether in antilocking or in drive slip control operation - a reduction in the locking or spinning tendency only appears after the modulator piston 28 has executed a relatively large stroke (recognisable from the position indicator output signal) in the direction of producing a brake pressure reduction or brake pressure build-up in the wheel brake subject to the control system, the electronic control unit 61 in each case assesses this as indicating that the vehicle is moving in a region of the track subject to low friction coefficients between the vehicle wheels and the track and that, in consequence, brake pressure restoration or brake pressure reduction phases have to be controlled correspondingly "carefully" and that it is desirable to interrupt them by brake pressure retention phases, as it were.

It is obvious that it is not possible to deal with all the possible control algorithms which are favourable for sensitive antilocking and drive slip control by using the information on the position of the modulator piston 28 and its changes obtainable from the position indicator 68. Such control algorithms could be taken into consideration in the case of obvious utilisation of the position indicator output signals and the output signals of the wheel rotational speed sensors and, if appropriate, the output signals of other sensors or signal generators which generate output signals characteristic of the functional condition of the power unit of the vehicle, e.g. the output signals from a throttle position indicator or a control linkage position indicator. However, the possibilities existing in principle have been sufficiently demonstrated by the case examples explained above and have to this

extent been indicated. It is therefore possible to dispense with the description of further obvious control cycle variants.

A number of important test functions concerning the functional readiness of the brake pressure setting device 10 and, in consequence, the antilocking and drive slip control equipment in total, can be controlled by means of the output signals, characteristic of the position of the modulator piston 28, of the position indicator 68.

These test functions could, for example, be carried out during a test cycle which is initiated automatically when the ignition is switched on or at a time selected by the driver by means of a test switch specially provided for that purpose. Examples which can be mentioned of this are:

1. Response and switch-over time of the functional control valve 46
2. Response and switch-over times of the pressure inlet control valve 37 and the brake pressure control valves 56 and 57
3. Ease of movement of the modulator piston 28
4. Leak-tightness of the pressure inlet control valve 37 and the brake pressure control valves 56 and 57.

Possibilities of use in carrying out such test cycles are thoroughly described in the Patent Application P 3,723,875.2-21 mentioned at the beginning and reference is made to the content of this application.

In a particular configuration of the brake pressure control device 10, its pressure modulator 21 is equipped with an electronic force sensor, indicated overall by 73, in its part shown "underneath" the central longitudinal axis 24. This sensor generates an electrical output signal whose level is a measure for the pressure present in the modulation chamber 34.

In this arrangement, the modulator piston 28' is of two-part design, the annular flange-shaped, larger piston step 42', which forms the movable boundary of the control pressure space 44 and the piston flange 32' which forms the

movable boundary of the modulation chamber 34 each forming a part of this piston 28'. The piston part 42' forming the larger piston step is provided with a short, sleeve-shaped guide seating 74 at its end facing towards the smaller piston step 32'. A similarly short, circular cylindrical guide extension 76 of the smaller piston flange 32 forming the boundary of the modulation chamber 34 protrudes in the axial direction into the guide seating 74. The two piston parts 42' and 32' are slightly displaceable relative to one another in the axial direction.

The electronic sensor element 81, which generates an electrical output signal whose level is the measure of the axial force, represented by the arrow 82, with which the smaller piston part 32' is pressed against the larger piston part 42' of the modulator piston 28', is located within a circular disc-shaped space 79 bounded by the end surface 77 of the cylindrical guide extension 76 of the smaller piston step 32' and the central region 78 of the inner end surface of the piston part forming the larger piston step 42' and its cylindrical sleeve-shaped guide extension 74. The sensor element 81 of the force sensor 73, whose output signal is therefore a measure of the pressure present in the modulation chamber 34, is represented - in the simplified representation - by a circular disc-shaped element which is clamped between the two piston parts 42' and 32' and is compressible to a greater or lesser extent (elastically) or can be deformed in the axial direction depending on the magnitude of the effective force within the circular disc-shaped space 79. It is assumed that the output signal of this force sensor 73 is respectively proportional to the axial compression or deformation of its sensor element 81.

Such a sensor element 81 can be achieved, in a manner known per se, by means of a piezo-electric crystal, e.g. a quartz plate, or by means of a deformation-sensitive resistance material, possibly with the help of strain guages which, for example, are arranged on a peripherally supported plate which, under the influence of the axial

forces acting on the piston flanges 32' and 42' is bent into a cap shape. Such sensors generate the output signal proportional to force or pressure within a favourably small deformation stroke and can therefore be effected with favourably small spatial dimensions so that they do not make any noticeable contribution to the installation size of the pressure modulator 21 or of its piston 28'.

The output signal of the force sensor 73, 81, providing a direct measure of the pressure in the modulation chamber 34 of the pressure modulator 21, can be used in an obvious manner, possibly in combination with the output signals of the wheel rotational speed sensors 62 and 63, for controlling pressure change phases of both the antilocking control system and the drive slip control system, particularly for controlling pressure addition, to suit the requirement, in the pressure build-up phases of both types of control.

The brake pressure setting device 10 can be bypassed in the particular illustrative example shown by means of a by-pass flow path, indicated in total by 83, by means of which, in case the pressure inlet control valve 37 should remain "stuck" in its shut-off position I in control operation due to a faulty function, brake pressure previously built up in the rear wheel brakes 11 and 12 can be again reduced. For this purpose, the two wheel brakes 11 and 12 are each connected via outlet non-return valves 84 and 86 respectively to a by-pass pipe 87 feeding back directly to the pressure outlet 38 of the tandem main cylinder associated with the rear axle brake circuit II. This by-pass pipe 87 can be shut off or opened by means of an outlet control valve 88 controlled by output signals of the electronic control unit 61. This outlet control valve 88 is designed as a 2/2-way solenoid valve whose basic position 0 is its through-flow position and whose actuated position I is its shut-off position. It is in each case directed jointly with the pressure inlet control valve 37 into its actuated position I and is switched back jointly with the pressure inlet control valve 37 into its basic

position 0.

The two outlet non-return valves 84 and 86 have a closing force equivalent to a pressure of a 2-4 bar and are each subjected in the opening direction to a pressure in the wheel brakes 11 and 12 which is higher than that in the by-pass pipe 87.

CLAIMS

1. Brake pressure setting device by means of which, in control phases of a control device stabilising the dynamic behaviour of a road vehicle by action upon its brake installation, brake pressure build-up, brake pressure retention and brake pressure reduction phases can be controlled, wherein

a) the wheel brakes of two driven vehicle wheels at least are combined in a static brake circuit, which

b) is connected via a pressure modulator and an electrically drivable inlet valve to an outlet pressure space of a brake unit,

c) the pressure modulator is designed as a stepped cylinder with two bore steps of different diameters in which a stepped piston, with two flanges of correspondingly different diameters, is guided so that it can be displaced in a pressure-tight manner, these flanges forming the axially movable boundaries of a modulation chamber and a control pressure space,

d) the modulation chamber is bounded by the smaller diameter piston step and is connected, on the one hand, via the pressure inlet control valve - in its basic position - to the outlet pressure space of the brake unit and, on the other hand, is permanently connected to the section of the main brake pipe, of the static brake circuit, branching off to the wheel brakes,

e) the pressure modulator is provided with a return spring which forces the modulator piston into its basic position associated with maximum volume of the modulation chamber,

f) the control pressure space bounded by the larger piston step can be alternatively connected, by means of an electrically drivable function control

valve, to the pressure outlet or the non-pressurised container of an auxiliary pressure source, whereby the stepped piston is displaceable - against the force of the return spring and the pressure present in the modulation chamber - as far as its end positions corresponding to the minimum volume of the modulation chamber and to the maximum volume of the modulation chamber,

g) electrically controllable brake pressure control valves individually associated with the wheel brakes are provided which can be driven individually or jointly from a basic position causing the connection between the particular wheel brake and the main brake pipe and permitting brake pressure build-up and pressure reduction phases into an alternative shutoff position which is associated with the brake pressure retention phases and

h) an electronic control unit is provided which generates signals, as required by the control system, for triggering the brake pressure control valves, the function control valve and the inlet control valve by processing output signals, characteristic of the motion behaviour of the vehicle wheels, of wheel rotational speed sensors, and wherein:

i) when a spin tendency appears on one of the driven vehicle wheels, the electronic control unit generates output signals by means of which the brake pressure control valves of the driven vehicle wheels are driven into their shut-off position (I) and the function control valve into its function positions causing pressure relief of the control pressure space of the pressure modulator, this occurring when the lower limiting values $\lambda_A 1$ and/or $b_A 1$ of the drive slip λ_A and/or the wheel peripheral acceleration b_A are exceeded, these lower limiting values being lower than the

threshold values ($\lambda_A 2$ and/or $b_A 2$) beyond which the use of a drive slip control system becomes necessary;

j) at the latest when the - higher - response threshold values $\lambda_A 2$ and/or $b_A 2$ are reached, the electronic control unit generates an output signal for switching the pressure inlet control valve into its shut-off position and an output signal which initiates the switching back into its basic position of that brake pressure control valve which is associated with the wheel with the tendency to spin and a signal which initiates the switching back of the function control valve into its basic position (0) causing the control pressure space to be connected to the pressure outlet of the auxiliary pressure source;

k) after the spin tendency has decayed, the electronic control unit generates that combination of its output signals which causes the switching back into their basic positions (0) of all the valves which can be electrically triggered.

2. Brake pressure setting device according to Claim 1, wherein the electronic control unit first generates, when the spin tendency decays, an output signal by means of which the control pressure space of the pressure modulator is again relieved to the container of the auxiliary pressure source and only then generates the output signal by means of which the inlet control valve is driven back into its through-flow position (0).

3. Brake pressure setting device according to Claim 1 or Claim 2, wherein the electronic control unit generates a signal causing the switching of the function control valve into its position connecting the control pressure space of the pressure modulator to the high pressure outlet of the auxiliary pressure source immediately after the pressure inlet control valve is switched into its shut-off position (I).

4. Brake pressure setting device according to any one of the preceding claims, wherein the pressure modulator is provided with a position indicator which generates an electrical output signal characteristic of the position of the modulator piston.

5. Brake pressure setting device according to any one of the preceding claims, wherein the modulator piston is provided with a force sensor which generates an electrical output signal characteristic of the pressure in the modulation chamber.

6. Brake pressure setting device according to any one of the preceding claims, wherein a by-pass flow path is provided which includes a by-pass pipe directly connected to the outlet pressure space, of the brake unit, associated with the brake circuit of the driven vehicle wheels, which by-pass pipe can be shut off by means of an outlet control valve and to which by-pass pipe each of the vehicle wheel brakes of the driven vehicle wheels is connected by means of an outlet non-return valve and this outlet control valve comprises a solenoid valve which can be driven into the throughflow and shut-off positions jointly with the inlet control valve.

7. Brake pressure setting device by means of which, in control phases of a control device stabilising the dynamic behaviour of a road vehicle by action upon its brake installation, brake pressure build-up, brake pressure retention and brake pressure reduction phases can be controlled, substantially as described herein with reference to, and as illustrated in, the accompanying drawing.

Published 1989 at The Patent Office. State House, 66-71 High Holborn, London WC1R 4TP. Further copies may be obtained from The Patent Office. Sales Branch, St Mary Cray, Orpington, Kent BR5 3RD. Printed by Multiplex techniques ltd. St Mary Cray, Kent, Con. 1/87