

BRAKE CONTROL FOR VEHICLES, ESPECIALLY FOR RAIL
VEHICLES AND A METHOD FOR CONTROLLING VEHICLE BRAKES

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Specification

The invention relates to a brake control according to the preamble of
Claim 1 and to a method according to the preamble of Claim 11.

10 When braking vehicles and vehicle trains, the driver, by way of a brake
pedal or a brake lever, normally defines a desired value of a brake force or of a
desired vehicle deceleration (so-called braking prompt). However, the actual
vehicle deceleration on the basis of this braking prompt depends on a plurality of
parameters which are not known to the driver, such as the condition of the brake
15 system, the loading of the vehicle, the slope of the road (gradient), the adhesion
value between the road and the wheels, etc. For example, in the case of
streetcars, it has therefore been attempted to regulate the brake system, in which
case the braking prompt was the desired value and the measured actual vehicle
deceleration was the actual value of the regulating. However, this resulted in
20 numerous difficulties. A main problem arose because of the fact that when
actuators of rail vehicle brake systems are operated, relatively long dead times
occur which, in the case of streetcars, are typically in the range of 0.7 seconds.
In addition, a relatively long time period (pressure buildup time) is required for
building up the braking force which is typically in the range of 1 second.

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Because of the inertia of such brake systems and because of diverse natural frequencies of undercarriages and other vehicle components, regulated braking operations can cause considerable jerking within the train formation, which is extremely undesirable. Thus, because of the above-mentioned difficulties, a stable regulating with a feedback in the classic sense, that is, with a continuous signal feedback, is hardly possible.

Another difficulty, which stands in the way of a classic regulating, is the fact that, when the actual value of the vehicle deceleration is defined by differentiating rotational wheel speed signals, which are supplied, for example, by inductive wheel sensors, relatively high percentage-related errors can occur which are the result of the scan timing and which, in the case of streetcars, are typically in the range of 100 milliseconds. These errors present an additional difficulty with respect to mastering the regulating.

It is therefore an object of the invention to provide a brake control and a method by means of which a stable braking can be implemented according to the braking prompt defined by the driver in the case of arbitrary parameters influencing the braking.

This object is achieved by means of the characteristics indicated in Claims 1 and 11. Advantageous embodiments and further developments of the invention are found in the subclaims.

The basic principle of the invention consists of arranging a regulating system behind the control, which regulating system will intervene by means of a correction signal only if the deviation between the braking prompt (as a desired deceleration signal) and the actual deceleration of the vehicle is outside a defined range. The corrected brake prompt signal will then be constant for the further control as long as the above-mentioned deviation is within the defined range. A change of the correction signal will not be effective until the above-mentioned deviation is outside the defined range.

The correction signal will be kept constant for one or several clock pulses as long as the difference between the "instantaneous deceleration signal" and the desired deceleration signal is within a defined value range. In contrast, the correction signal is changed from one clock pulse to the next when the instantaneous deceleration is outside this "tolerance band".

In comparison to a classic analog control or a conventional digital control, in which, during the entire regulating operation, a control variable is continuously fed back and processed, in the case of the signal processing according to the invention, the instantaneous deceleration, which can be understood to be the control variable, will be processed, that is, used for generating the correction signal, only when the difference between the desired deceleration signal and the instantaneous deceleration, which can be understood to be the "regulating deviation", with respect to its amount becomes too large, that is, is outside the tolerance band. When, in contrast, the regulating deviation is so small that the



difference is within the tolerance band, the instantaneous deceleration is not processed and the correction signal is maintained unchanged.

5 Since the "regulating intervention" takes place only in the case of larger deviations and otherwise the control is unregulated, the initially mentioned dead times and pressure buildup times can be mastered better.

10 In addition, existing brake systems can be retrofitted with a brake control according to the invention without having to change mechanical components of the existing brake system.

15 The invention can be implemented as a hardware solution in the form of an electronic circuit as well as as a software solution in the form of a computer program for a program-controlled processor or as a combination of the two solutions. Particularly a software-type implementation allows a very cost-effective adaptation of the existing brake control to a certain vehicle and to certain application conditions.

20 According to a further development of the invention, a measured "course" or a "course" of time-discrete instantaneous deceleration signals is smoothed. This takes place in that a smoothed instantaneous deceleration signal is formed from an actual measured value, which represents the instantaneous deceleration of the vehicle , and from measured values of preceding clock pulses. The smoothing takes place by a special filtering which consists of the fact that a



number of successively taken measured values are weighted differently and a weighted average value is formed from these weighted measured values. In this case, the weighting is defined such that the measured values which, with respect to time, are close to the actual measuring point in time are weighted higher than the measured values which are more remote with respect to the time. In contrast to a frequency filtering, for example, by means of a low-pass filter, no signal transformations are therefore obtained in the time range. By means of such a smoothing of the course of the deceleration signal, errors can be reduced which are made during the measuring or during the calculation of the individual time-discrete instantaneous decelerations. On the whole, this results in a smoother course of the correction signal and therefore in braking operations with fewer jolts.

According to a further development of the invention, a "correction signal gradient" formed by two successive correction signals, in the event of the exceeding of or the falling below a defined positive or negative maximal gradient, is limited to this maximal gradient. This has the advantage that deceleration jolts and resulting force impulses at the vehicle or within a vehicle formation during the braking operation are further minimized. This reduces the mechanical stress to the vehicle, and the travelling comfort for the passengers is simultaneously increased.

In the following, the invention will be explained in detail by means of an embodiment in connection with the drawing.

Figure 1 is a block diagram of a brake control according to the invention;
and

Figure 2 is a schematic block diagram of a brake system of a vehicle
5 which is equipped with a brake control according to the invention.

In Figure 1, a generator G, which may, for example, be a brake lever,
generates a mechanical signal which, by means of an electro-mechanical
converter 1', is converted to an analog electrical braking prompt signal BAZ for
10 the train unit and which represents a desired deceleration of the vehicle to be
braked which was requested by the driver. This braking prompt signal BAZ is
supplied by way of a signal converter 1 with an integrated A/D converter as a
digital signal BA to a jolt limiting circuit 3 which limits the rising and falling
gradient of the signal BA and emits a "filtered" braking prompt signal BAR. If
15 the signal BAZ defined by the drivers changes, for example, in the event of an
abrupt initiating of a full braking or a sudden release of the brake, the jolt limiting
circuit 3 has the effect that its output signal BAR can change within a defined
time interval, for example, a clock pulse, only by a defined value in comparison
to the previous clock pulse. This filtered braking prompt signal BAR is the
20 "normal" output signal of the control which is supplied to actuating elements of
the brake. In the case of the invention, this signal is modified when certain
operating conditions occur. An adder 5 is provided for this purpose, to whose
one input the signal BAR is supplied and to whose other input a correction signal

K is supplied. The output of the adder 5 then supplies the control signal S supplied to the actuating elements of the brake.

5 The correction signal K is generated in a subordinate control circuit. For this purpose, by measuring the rotational speed of one or several wheels of the vehicle, a measuring sensor M detects a signal v which represents the instantaneous speed of the vehicle and which is differentiated with respect to time in a differentiator 8, whereby a signal b_i is obtained which represents the vehicle acceleration or deceleration. This signal - which, in the following, will be called
10 "deceleration signal" - is intermediately stored in a memory element 10, in which case the memory element 10 can store several successive measured values, such as four or five successive deceleration signals.

The deceleration signal measured at the actual point in time and several
15 deceleration signals of previous clock pulses determined during preceding measurements and stored in the memory element are supplied to a filter element 11 and are "filtered" by it.

The filter element 11 is a digital numerical filter which, in general terms,
20 carries out only an amplitude standardization of successive deceleration signals but no frequency filtering and thus smoothes the time behavior of the signal course formed by the deceleration signals. The basic principle of this filter consists of the fact that the actual deceleration value is multiplied by a relatively high weighting factor, while the deceleration values of the preceding

measurements are multiplied by smaller weighting factors. The individual multiplied values are added up and are divided by the sum of the individual weighting factors. This relationship is defined in the following calculation formula:

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$$F_j = \frac{G_0 b_0 + G_{-1} b_{-1} + \dots + G_{-n} b_{-n}}{b_0 + b_{-1} + \dots + b_{-n}}$$

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$$F_j = \frac{\sum_{i=-n}^0 G_i b_i}{\sum_{i=-n}^0 b_i} ; i, j, n \in \mathbb{N}$$

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wherein F_j is a deceleration signal smoothed by the filter element 11 at the point
 25 in time j , which deceleration signal corresponds to the smoothed signal b of
 Figure 1. F_j is calculated from individual deceleration values b_i , wherein b_0
 corresponds to the value of the instantaneous deceleration signal of the actually
 considered clock pulse, b_{-1} corresponds to that of the preceding clock pulse, etc.
 The factors G_i are weighting factors which are indexed corresponding to the
 30 deceleration values b_i , wherein the following applies here: $G_i > G_{i-1}$. Thus, the
 "past" has a lower weight than the "present" but nevertheless causes a smoothing,
 so that undesirable peaks are avoided in the deceleration signal b .

For the purpose of a clarification, a concrete calculation formula will be indicated in the following, in which, in addition to the instantaneous deceleration signal b_0 , four values preceding it are taken into account and are weighted corresponding to their succession in time by means of weighting factors 1 to 5.

$$F = \frac{5 b_0 + 4 b_1 + 3 b_2 + 2 b_3 + 1 b_4}{5 + 4 + 3 + 2 + 1}$$

When filtering functions are used in which the arguments b_i occur linearly, it is possible to arrange the differentiator 8 behind the filtering element; that is, to first filter speed signals v and to differentiate subsequently.

The smoothed deceleration signal b is supplied to a subtracter 13 and is subtracted there from the filtered braking prompt signal BAR. By way of a switch 15, the thus generated differential signal Δb is supplied to two comparators 17 and 18. The switch 15 is used for switching off the control circuit, which is arranged on the output side, at certain operating conditions; for example, when there is a falling below a defined minimum speed of the vehicle; at certain locking conditions, for example, when all wheels of the vehicle have the tendency to lock; when the blocking brake is engaged, etc. In the normal condition, the switch 15 is in the illustrated ON-position.

The comparators 17 and 18 are each followed by multipliers 19 and 20. The arrangement of the comparators 17 and 18 and of the multipliers 19 and 20 has the purpose of providing different regulating amplifications for positive and negative deviation signals Δb . Comparator 17 therefore allows only a signal Δb

to pass which is > 0 , while comparator 18 allows only a signal Δb to pass which is < 0 . In the multipliers 19 and 20, the corresponding signals are then multiplied by the different factors $K1$ and $K2$. If signal Δb is exactly 0, the two comparators 17 and 18 are blocked; a "regulating intervention" is not necessary.

5 The output signals of the multipliers 19 and 20 are supplied to a common connection of a switch 22, which is controlled by a logic signal F of a window comparator 24.

The filtered braking prompt signal BAR and the smoothed deceleration

10 signal b are supplied to the window comparator 24. The braking prompt signal BAR is multiplied in a first multiplier 31 by a factor $A1$ and in a second multiplier 32 by a factor $A2$. The output signals of the multipliers 31 and 32 are compared in the comparators 33 and 34 with the deceleration signal b . The comparators 33 and 34 are followed by threshold value comparators 35 and 36,

15 in which it is examined whether the output signal of the comparator 33 is smaller than or equal to 0 or whether the output signal of the comparator 34 is larger than 0. The output signals of the two comparators 35 and 36 are linked with one another in an AND gate 38, which emits the signal F .

20 By means of the window comparator 24, a value range of $(BAR * A1 - b)$ and $(BAR * A2 - b)$ is defined and examined as to whether the smoothed deceleration signal b is within this value range or window. The width and the position of this window with respect to the smoothed deceleration value b are determined by the factors $A1$ and $A2$. If the smoothed deceleration signal b is

within the thus defined window, no correction of the braking prompt signal BAR is required. If, on the other hand, the signal b is outside this window, the switch 22 will be in the position illustrated in Figure 1, and the difference signal Δb , as re-quired, modified by the factors K1 and K2, by way of a gradient limiting circuit 25, will be supplied to a memory 28 to whose control input the signal F is also supplied by the window comparator 24. The memory 28 will then store the gradient-limited differential signal Δb which is multiplied by the factors K1 or K2 and which is supplied as the correction signal K by way of a switch 52 to an input of the adder 5. The gradient limiting circuit 25 operates in the same manner as the jolt limiting circuit 3 and permits within a defined time period of, for example, two successive clock pulses, only a maximal change by a defined value.

The output signal K of the memory 28 is compared in a comparator 50 with a fixedly defined negative value -x. The output signal of the comparator 50 controls the switch 52. It is the purpose of this measure to permit negative correction values only to a fixedly defined value -x. The braking prompt signal BAR injected by the driver can therefore only be reduced by this value -x. This prevents, for example, a complete releasing of the brake in the case of an uphill braking. If the output signal K of the memory 28 is negative and mathematically smaller than the value -x, the switch 52 is switched, and a fixed value -x is supplied to the corresponding input of the adder 5. The value -x can also be selected at zero if no corrections reducing the braking prompt BAR but only corrections are to be permitted which increase the braking prompt BAR.

If the output signal F of the window comparator 24 indicates that the smoothed deceleration signal b is within the window, the switch 22 is switched, and the correction value K is maintained which was last stored in the memory 28. For this purpose, in the wiring diagram of Figure 1, the output of the memory 28 is connected with the other input 30 of the switch 22, so that the output value of the memory 28 is supplied by way of the switch 22 and the gradient limiting circuit 25 to the input of the memory 28.

As a result, it is achieved that a correction value once determined during a "leaving" of the value range defined by the comparator 24 will be maintained until the smoothed vehicle deceleration b again leaves the defined value range.

The following will explained concerning the value range of the window comparator:

If, for example, the constant A1 has the value 1.0 and the constant A2 has the value 1.1, the logic signal F emitted by the window comparator will have the logical value "1" precisely when the value of the deceleration signal b is in a range between 1.0 times the value of the braking prompt signal BAR and 1.1 times the value of the signal BAR. When the smoothed deceleration signal b is outside this "tolerance range" defined by the two constants A1 and A2 as a function of the value of the signal BAR, the signal F emitted by the window comparator 24 will have the logical value "0", which corresponds to the illustrated position of the switch 22.

In the case of the control with the regulating intervention illustrated in Figure 1, four different cases can occur which will be explained in the following, the constants A1 and A2, for example, having values "1.0" and "1.1". In addition, the de-scription of the four cases will relate to the position of the switch 52 illustrated in Figure 1 (it is to be assumed that the value of the signal 29 is greater than the negative value "-x").

In a first case, it will be assumed that the smoothed deceleration signal b formed from the speed signal v is equal to 0.95 times the filtered braking prompt signal BAR; that is, the actual deceleration is smaller than the deceleration prompted by the driver, in which case the signal b is outside the tolerance band. In this case, the signal F has a logical value "0", so that the switch 22 is in the illustrated position and the memory element 28 is switched into a storage-ready condition. Since the actual deceleration of the vehicle is smaller than the deceleration prompted by the driver, the differential signal Δb will be positive and will therefore be multiplied in the multiplier 19 by the factor K1 and will be emitted as signal 21 by way of the switch 22 to the gradient limiting circuit 25.

Signal 26 increases its value with the gradient which is provided by the gradient limiting circuit 25. The memory 28 correspondingly increases its stored value. By way of the switch 52 in the illustrated position, this value is emitted as the correction value K and is added to the braking prompt signal BA and the signal S rises correspondingly. The vehicle deceleration will rise, specifically as long as the supplied deceleration signal b is moving into the permissible value range of the window comparator 24, in which case its output signal F assumes the

logical value "1". The value in the memory 28 will remain unchanged as long as the signal F has a logical value "1".

It will be assumed that, in case 2, the deceleration signal b will be increased in comparison to case 1 and will, for example, be equal to 1.05 times the braking prompt signal BAR and will therefore be within the tolerance range. In this case, signal F has the logical value "1" and switches the switch 22 to the contact 30 and simultaneously switches off the storage readiness of the memory element 28. Although, in this case, a differential signal Δb and therefrom a signal 21 continue to be generated, this signal is further processed. In this case, the value 29 of the preceding clock pulse filed in the memory 28 is again supplied to the adder 5 as the correction signal K and the output signal S is formed therefrom.

It is assumed that in the third case - for example, in a subsequent clock pulse - the smoothed deceleration signal b is equal to 1.2 times the filtered braking prompt signal BAR and is therefore again outside the tolerance band so that the switch 22 will be switched back again into the illustrated position and the memory element 18 is changed into the storage-ready condition. The differential signal Δb is negative in this case and is multiplied in the multiplier 20 by the factor K2. After passing through the gradient limiting circuit 25, the new value 29 is written into the memory 28 and is supplied as the correction signal K to the adder 5.

It is assumed that in a fourth case the smoothed deceleration signal b is equal to the filtered braking prompt signal BAR , so that the differential signal Δb has the value "0" and the switches 15 switches, which has the result that no correction signal K at all is emitted. Thus, the output signal S is equal to the
5 filtered braking prompt signal BAR .

In a supplementary manner, it is pointed out that the control with the regulating intervention according to the invention can be integrated into the overall brake system such that, in certain operating conditions, it is automatically
10 or manually switched off by the switch 15 or can be switched off or overdriven by another component system, such as an antiskid system. A switching-off and an intervention of an antiskid system is useful, for example, when all axles of a vehicle or of a vehicle formation have the tendency to lock.

15 Figure 2 is a schematic block diagram in which the deceleration control with the regulating intervention illustrated in Figure 1 is a component of an overall vehicle brake system. In Figure 2, the deceleration control with the regulating intervention illustrated in Figure 1 is combined in a block marked R . The braking prompt signal BAZ defined by the driver is fed to the block R as
20 well as the deceleration signal b_i obtained from the vehicle speed v by differentiating in the differentiator 8. From the signals BAZ and b_i , the deceleration control with the regulating intervention generates the control signal S which is supplied to a load detection unit L . In addition, load signals LS are

supplied to the load detection unit L, in the schematic representation of Figure 2 only one signal path LS being shown.

5 When looking at a brake system of a train, the number of load signals LS, for example, corresponds to the number of bogies of the train; that is, the load to be carried by each bogie is processed. As a function of the possibly different loads of individual bogies, the load detection unit L generates a corresponding number of output signals 44, which are supplied to a converter 45.

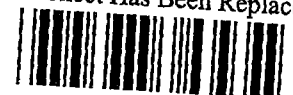
10 The, for example, electro-pneumatic converter 45 converts the signals 44 into forces or pressures which operate braking mechanisms 47 (such a brake cylinders or calipers) at the as-signed bogies, which causes a braking and therefore changes the speed v . From a new speed v occurring in the next clock pulse, a new deceleration b is calculated which is again supplied to the
15 deceleration control with the regulating intervention R.

 The additional detection of load signals LS is advantageous in order to, for example, prevent in the case of a train that the braking forces generated from the brake control signal S are supplied only to the brakes of one bogie while the
20 other bogies remain unbraked.

CLAIMS:

- 5 1. Brake control for vehicles, particularly rail vehicles, having a generator which can be operated by the driver for generating a braking prompt signal (BAZ) and having a control which is connected with the generator and which, as a function of the braking prompt signal, generates a brake controlling output signal (S),
- 10 characterized by
- a measuring device (8, 10, 11) which generates a deceleration signal (b) corresponding to the vehicle deceleration,
 - a window comparator (24) which examines whether a difference between the braking prompt signal (BAR) and the deceleration signal (b) is
 - 15 within a predefined range and which generates an output signal (F) corresponding to the result of this examination,
 - a correction value device (6) which generates a correction signal (K) corresponding to the difference between the braking prompt signal (BAR) and the deceleration signal (b), and
 - 20 - a linking device (5) which modifies the braking prompt signal (BAR) corresponding to the correction signal (K), a modification by means of a correction signal (K) changed with respect to the past taking place only when the output signal (F) of the window comparator (24) indicates that the difference

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between the braking prompt signal (BAR) and the deceleration signal (b) is outside the predefined range.

2. Brake control according to Claim 1,
5 characterized in that the measuring device (8, 10, 11) has a filtering device (10, 11) which processes several successive time-discrete measured values (b_i) of several successively measured deceleration signals (b_i) to form the deceleration signal (b).

10 3. Brake control according to Claim 2,
characterized in that the filtering device (10, 11) weights the measured values (b_i) differently which are to be processed during a clock pulse.

4. Brake control according to Claim 3,
15 characterized in that the weighting takes place by means of different weighting factors (G_i), measured values (b_i) which were measured later in time being weighted higher than measured values (b_i) which were measured earlier in time.

5. Brake control according to one of Claims 1 to 4,
20 characterized in that the correction value device (6) has a gradient limiting device (25) which limits the variation in time of the correction signal (K, 26, 29) to a defined amount.

6. Brake control according to Claim 5,

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characterized in that correction value device (6) has a memory device (28) which stores a signal (29) supplied by the gradient limiting device (25) when the output signal (F) supplied by the window comparator (24) has a defined value.

5 7. Brake control according to one of Claims 1 to 6,
characterized in that the correction value device (6) has a regulating amplification device (19, 20, 22) which amplifies a difference signal (Δb) formed from the braking prompt signal (BAR) and the deceleration signal (b) to different degrees as a function of its preceding sign and supplies it to the gradient limiting device
10 (25) if the output signal (F) generated by the window comparator (24) has a defined value.

8. Brake control according to one of Claims 1 to 7,
characterized in that the correction value device (6) has a limiting device (50, 52)
15 which limits a correction signal (K), which is generated for reducing the braking prompt signal (BAR), to a defined amount (-x).

9. Brake control according to one of Claims 1 to 8,
characterized in that a switching device (15) is provided which switches the
20 correction value device (6) on and off as a function of defined conditions, such as a vehicle speed, a value of an antiskid signal, a value of a brake signal, the types of mutually coupled vehicles, or the like.

10. Brake control according to one of Claims 1 to 9,



characterized in that a jolt limiting device (3) is provided which generates the braking prompt signal (BAR) from a signal (BAZ) supplied by the generator (G) and which limits the variation in time of the braking prompt signal (BAR) to a defined amount.

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11. Method for controlling vehicle brakes, particularly rail vehicle brakes, wherein a brake controlling brake output signal is generated from a braking prompt signal to be defined by a driver, characterized by

- 10 - measuring the vehicle deceleration (b_i) and generating a corresponding deceleration signal (b),
- determining a difference between the braking prompt signal (BAR) and the deceleration signal (b),
- generating a correction signal (K) corresponding to the difference
- 15 between the braking prompt signal (BAR) and the deceleration signal (b), examining whether the difference is inside or outside a defined range, and
- modifying the braking prompt signal (BAR) corresponding to the correction signal (K) only when the difference between the braking prompt signal (BAR) and the deceleration signal (b) is outside the predefined range.

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12. Method according to Claim 11, characterized by a processing of several time-discrete measured values (b_i) of several successively measured deceleration signals to form the deceleration signal (b).

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13. Method according to Claim 12,
characterized by differently weighting the measured values (b_i) to be pro-cessed
during a clock pulse.

5 14. Method according to Claim 13,
characterized by a weighting by means of weighting factors (G_i) during which
measured values (b_i) which were measured later in time are weighted higher than
measured values (b_j) which were measured earlier in time.

10 15. Method according to one of Claims 11 to 14,
characterized by a limiting of the variation in time of the correction signal (K) to
a defined amount.

15 16. Method according to Claim 15,
characterizing by a storage of the possibly limited correction signal (K) under the
condition that the difference between the braking prompt signal (BAR) and the
deceleration signal (b) is within the defined range.

20 17. Method according to one of Claims 11 to 16,
characterized in that an amplification is carried out of a difference signal (Δb)
formed from the braking prompt signal (BAR) and the deceleration signal (b), the
difference signal (Δb) being differently amplified as a function of its preceding
sign.

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18. Method according to one of Claims 11 to 17,
characterized by a limiting of a correction signal (K), which is generated for
reducing the braking prompt signal (BAR), to a defined amount (-x).

5 19. Method according to one of Claims 11 to 18,
characterized in that the generating of a correction signal (K) is carried out or not
carried out as a function of defined conditions, such as a vehicle speed, a value
of an antiskid signal, a value of a brake signal, the types of mutually coupled
vehicles, or the like.

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