PATENT SPECIFICATION

(11) 1 269 446

DRAWINGS ATTACHED

1 269 446

(21) Application No. 38831/70 (22) Filed 12 Aug. 1970
(31) Convention Application No. 52994 (32) Filed 13 Aug. 1969 in
(33) Italy (IT)
(45) Complete Specification published 6 April 1972
(51) International Classification B 60 t 8/12
(52) Index at acceptance
F2F 3G

(54) MODULATING DEVICE FOR A WHEEL BRAKE ACTUATOR

(71) We, LANCIA & C. FABBRICA AUTOMOBILI TORINO S.p.A., an Italian company, of Via Vincenzo Lancia 27, Torino 10141, Italy, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following specification:—

This invention refers to a modulating device for a wheel brake actuator for use in vehicles provided with anti-skid braking systems, that is, systems which reduce the tendency of a braked wheel to lock and skid.

In anti-skid braking systems the angular velocity of the braked wheel is monitored, and steps are taken automatically to reduce or eliminate the braking action independently of the driver's control of the brakes when the wheel deceleration exceeds a certain predetermined value, indicative of possible imminent locking of the wheel.

It is already known to observe the angular velocity of a wheel and to give a continuous voltage signal, representative of the said velocity. It is also known to provide an electrically operated valve, or solenoid valve, for modulating the operation of a brake actuator.

However, modulating devices incorporating solenoid valves have in practice to exhibit high stability and sensitivity. In particular, the modulating device should be stable so that its conditions of operation do not change with variations of temperature, or environment, or with variations of such parameters such as supply voltage, and the age of the component parts, for example. The device must above all be sensitive, so that abnormal deceleration of the wheel causes a prompt operation by the solenoid valve. This sensitivity is particularly difficult to achieve in practice, since the difference between the optimal wheel deceleration for most effective braking (which corresponds to the greatest friction coefficient between the wheel and the ground) and the deceleration level at which wheel locking or skidding is imminent, either by reason of locking of the wheel, or else by reason of diminished friction coefficient, is very small, in the order of a very few per cent. A delayed operation of the modulating device could lead to undesirable wheel locking; on the other hand, if the modulating device were to intervene too soon it could prevent the braking action from taking advantage of the greatest friction coefficient between the wheel and the ground, leading in consequence to lessening of braking efficiency and increased stopping distance for the braked vehicle.

An object of the invention is to provide a modulating device for a wheel brake of the aforesaid type, which is capable of operating with great stability under temperature variations.

A further object of the invention is to provide a modulating device of the said type which lends itself to economical manufacture and mass production, with a minimum of adjustment being required.

According to the present invention there is provided a modulating device for a wheel brake actuator for a vehicle anti-skid braking system, said device being responsive to a continuous input signal which is inversely proportional to the angular velocity of the vehicle wheel, the device comprising in combination:

(a) a differentiating means which is adapted to receive the said continuous input signal and to provide a second signal proportional to the deceleration of the said wheel;

(b) a first transistor responsive to the said second signal, and adapted to provide a third signal proportional to the second signal;

(c) a second transistor of the complementary conductivity type to the first transistor, the collector of the said second transistor being connected to the collector of the first transistor and the base of the said second transistor being supplied with a stabilised direct current voltage through a Zener diode, so that the said second transistor maintains the collector current of the first transistor substantially constant;

(d) a flip-flop circuit arranged to receive the said third output signal of the first transistor, being in a first state, and having a first output voltage, when said third signal is lower than a pre-determined threshold value, and being in a second state, and having a second output voltage, when the said third signal is greater than said pre-determined threshold value;

(e) electro-mechanical means for controlling a brake actuator, said means being controlled by the output voltage of the said flip-flop circuit and interrupting operation of the brake actuator when the flip-flop circuit is in said second state.

The modulating device of the invention in its preferred embodiments is very sensitive to wheel deceleration signals and can provide a modulating control signal with a very small delay.

The modulating device of the present invention is capable, in its preferred embodiments, of effective operation for braking on road surfaces under the most varied of conditions, for example, dry, wet, or snow-covered roads.

The invention will be more clearly understood from the following description, given by way of example, with reference to the attached drawings, in which:—

Figure 1 is a block schematic diagram illustrating the overall operation of a braking system incorporating a modulating device according to the invention;

Figure 2 is a circuit diagram of a control device according to one embodiment of the invention;

Figure 3 is a graph which illustrates the mode of operation of a direct current amplifier which forms part of the modulating device of Figure 2; and

Figure 4 is a circuit diagram of an alternative operational embodiment of the invention, for use in controlling the braking of a pair of wheels.

The overall mode of operation of a practical braking system in which the modulating control device according to this invention is incorporated will first be described with reference to Figure 1.

In Figure 1, 10 indicates a manual brake control member, usually a pedal, which is operated by the driver of a vehicle. The control member 10 controls the supply of fluid pressure to an hydraulic actuator 12. Alternatively, the actuator 12 may be operated directly or by power brake servo. The actuator 12 applies a brake 14 which acts on a wheel 16 to reduce the vehicle speed.

An angular velocity sensing device 18 provides a direct current continuous signal the amplitude of which is inversely proportional to the angular velocity of the wheel 16. The sensing device 18 can be of a conventional known type.

A modulating device for the actuator 12, in accordance with the invention, comprises a circuit 20 for processing the angular velocity signal provided by the sensing device 18, and a solenoid valve 22. When the deceleration of the wheel exceeds a certain predetermined limit, the circuit 20 energises the solenoid valve 22, which momentarily releases the actuator 12, eliminating or reducing the braking force applied to the wheel 16 by the brake 14.

Thereupon, as a result of the reduction or elimination of the braking force, the respective wheel 16 starts to turn again with the appropriate angular velocity: the circuit 20 then generates a signal of opposite polarity which de-energizes the solenoid valve 22, causing the actuator 12 to re-apply the brake 14. This sequence of operation repeats itself cyclically for as long as the brake 14 is applied by the manual control member 10.

The time delay inherent in the electronic circuit 20 is negligible, and the time delay for operation of the actuator 12 is in practice extremely small, so that the above-described sequence of operations occurs many times during the time that the brake is applied.

The operation of the device according to the invention will now be described in more detail with reference to Figure 2, which shows the circuit diagram of the device. A direct voltage input signal V_{in} provided by the sensing device 18 is inversely proportional to the wheel speed.

The input signal V_{in} is applied to a capacitor C_8 which acts as a differentiator to pass variations in the voltage V_{in} to the base of a transistor T_8. Both positive and negative variations are passed by the capacitor C_8, resulting in the transistor T_8 being driven into a condition of lower or higher conduction, respectively. A transistor T_9 of complementary conductivity type i.e. NPN, is connected with a common collector to the transistor T_8 to provide amplification and switching over a wide range of temperature as hereinafter described.

The transistor T_8 constitutes a direct current amplifier of high sensitivity, the base emitter voltage of which is compensated for variations of temperature by the inclusion in the base-biassing network of an impedance, in this case a thermistor R_{26}, which varies with temperature. The voltage at the base of T_9 is stabilised b ythe action of a Zener diode D_6 connected to the base of T_9, and connected to the negative earth return rail through a resistor R_{30}. By virtue of its stabilised base voltage the transistor T_9 provides a constant collector current for the transistor T_8. The base of T_9 is connected to the positive rail through resistors R_{27} and R_{28}. A limiter resistance R_{29} is connected to the emitter of T_9.

By arranging that the collector current of T_8 is constant in this way, the transistor T_8 in effect presents an infinite resistance: very small variations of the base current of T_8 will suffice to displace the working point of the collector of T_8 from its regulated value to a value, close to that of saturation of T_8, which is greater than the threshold of conduction of a Zener diode D_7 connected to the collector of T_8. The regulated value of the working point of the collector T_8 is determined, with a constant voltage input to the device, by means of a variable resistor R_{25bis} in the base circuit of T_8.

Figure 3 shows the collector current/voltage characteristics of transistor T_8. By arranging, as aforesaid, for the collector current I_c of T_8 to be constant, the collector working point lies along the line I_c=const, corresponding to infinite resistance. Since the collector current/voltage curves of transistors are in general characterised by a very high dynamic resistance in the working region, illustrated for two base currents I_{B1} and I_{B2}, an extremely small variation (in practice, of the order of 2%—3%) of the base current I_B induces a very considerable change in the collector voltage V_{ce}. Thus as shown, the small change in base current from I_{B1} to I_{B2} is accompanied by a collector voltage change from V_1 to V_2.

A flip-flop circuit comprising two transistors T_{10} and T_{11} is arranged so that transistor T_{10} is conducting in the quiescent, or first, state of the circuit through a diode D_{10} and resistor R_{32}. The diode D_{10} is cascaded with a diode D_{11}, both of which are maintained normally conducting through a resistor R_{35}, the transistors T_{10} and T_{11} sharing the diode D_{10} in a common collector configuration to allow rapid switching.

The Zener diode D_7 transmits the change of voltage at the collector of T_8 to the base of the transistor T_{10} which, being normally conducting, now becomes non-conducting, causing conduction of T_{11} thereby causing the circuit to enter its second state. The collector of T_{11} is connected to the base of an output transistor T_{12} through a resistor R_{37}, the base of the transistor T_{12} being also connected to earth through a resistor R_{38}. Conduction of T_{11} as aforesaid therefore causes conduction of T_{12}.

The conduction of the transistor T_{12} causes energisation of the solenoid R of the solenoid valve 22, which is operated to interrupt the operation of the actuator 12. A resistor R_{33} is connected in series with the solenoid R with the object of reducing the time constant of operation of the solenoid valve 22. A capacitor C_9 and resistor R_{41} in series are connected in parallel with the solenoid R with the object of allowing a predetermined delay in the deenergisation of the solenoid R when current through the latter ceases.

A negative variation, that is, a reduction, in the input voltage V_{in} is not transmitted to the base of T_8, in contrast to a positive variation. The capacitor C_8 having in this case to discharge, acts preventively on the base of T_8, while a diode D_5 connected to the base of T_8 discharges C_8 through the resistor R_{28} very quickly, thus further contributing to the preventive action and protection of the transistor T_8.

The supply voltage, drawn from the vehicle battery, is delivered to the device which is the subject of the invention by way of a suitable stabilizer (not shown) of the conventional type, which serves to provide the positive supply voltage V_2 (+), making use of a Zener diode (not shown) to provide a reference voltage and employing a conventional transistor stabiliser circuit to provide a stabilised voltage even for wide variations of battery voltage.

In applying the anti-skid system, including the modulating device according to the invention, to a pair of vehicle wheels, for example to the two rear wheels of a motor vehicle, it is necessary that excessive slowing down (indicating locking) of one or the other (or both) of the wheels shall give rise to a reduction in the braking action upon both wheels.

It is of course possible to install two independent control systems as previously described, one for each wheel, arranged to control a common solenoid valve, having, for example, two solenoid windings.

However, for reasons of economy, a further operational embodiment of the invention, illustrated in Figure 4, may be employed. Instead of duplicating the whole modulating device of Figure 1, it is found preferable to duplicate only the first part, is being possible, by the use of two decoupling diodes as subsequently described, to use for both wheels a common second part of the electronic circuit. As can be seen in Figure 4, the part of the circuit comprising the capacitor C_8 and the transistors T_8, T_9 and T_{10} with their associated passive circuit components, has been duplicated. Corresponding circuit components in the duplicated parts bear the same reference numerals, unprimed for one part (the upper parts in Figure 4) and primed in the other part. The said two corresponding circuit parts have two points of connection to a common second circuit part which consists of the transistors T_{11} and T_{12}, and their associated passive components. The said two connection points are the points A and B, also marked in Figure 2. Into the point B there flow the emitter currents of T_{10} and T_{10}^1. The point A is connected to the collectors of T_{10} and T_{10}^1 through decoupling diodes D_8 and D_8^1 which prevent interaction between the two first circuit parts. The two respective signals V_{in} and V_{in}^1 supplied by respective first and second wheels will thus both operate independently upon the modulating device.

As shown in Figure 4, it is also possible to use a common base voltage stabilising network R_{39}, D_6 for both the transistors T_9 and $T_9{}^1$ by interconnecting the points Z_1, that is the bases of T_9, $T_9{}^1$, thereby achieving a further economy of circuit components.

It will be appreciated that the specific operational examples of the invention as described can have numerous possible variants. In particular the flip-flop circuit consisting of the transistors T_{10} and T_{11}, with their associated passive components, can be replaced by any other equivalent electronic circuit. Moreover the output transistor T_{12} could be omitted, or replaced by a similar electronic or electro-mechanical device, provided the output signal of the flip-flop circuit, derived in the illustrated examples from the junction of the resistors, R_{33} and R_{37} is powerful enough to energise the solenoid R.

WHAT WE CLAIM IS:—

1. A modulating device for a wheel brake actuator for a vehicle anti-skid braking system, said device being responsive to a continuous input signal which is inversely proportional to the angular velocity of the vehicle wheel, the device comprising in combination:

(a) a differentiating means which is adapted to receive the said continuous input signal and to provide a second signal proportional to the deceleration of the said wheel,

(b) a first transistor responsive to the said second signal, and adapted to provide a third signal proportional to the second signal;

(c) a second transistor of the complementary conductivity type to the first transistor, the collector of the said second transistor being connected to the collector of the first transistor, and the base of the said second transistor being supplied with a stabilised direct current voltage through a Zener diode so that the said second transistor maintains the collector current of the first transistor substantially constant;

(d) a flip-flop circuit arranged to receive the said third output signal of the first transistor, being in a first state, and having a first output voltage, when said third signal is lower than a predetermined threshold value, and being in a second state, and having a second output voltage, when the said third signal is greater than said pre-determined threshold value;

(e) electro-mechanical means for controlling a brake actuator, said means being controlled by the output voltage of the said flip-flop circuit and interrupting operation of the brake actuator when the flip-flop circuit is in said second state.

2. A device as claimed in claim 1, in which variation with temperature of the base-emitter current of the first transistor is compensated by a network including at least one circuit element the impedance of which varies with temperature.

3. A vehicle anti-skid braking system having an actuator adapted to operate brakes on a pair of wheels of a motor vehicle, the system including a pair of modulating devices according to claim 1 or claim 2, the first of which devices receives an angular velocity signal from a first wheel of said pair, and a second of which devices receives an angular velocity signal from the second wheel of the pair, said devices acting in common upon the said brake actuator of the said pair of wheels.

4. A modulating device for a wheel brake actuator, substantially as herein described with reference to and as shown in the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1972.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY,
from which copies may be obtained.

FIG. 1

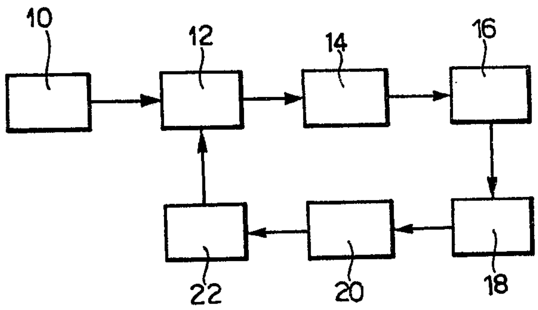
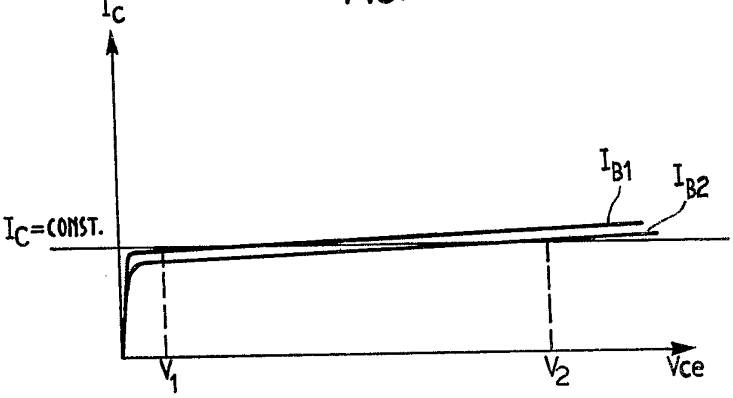


FIG. 3



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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 2

FIG. 2

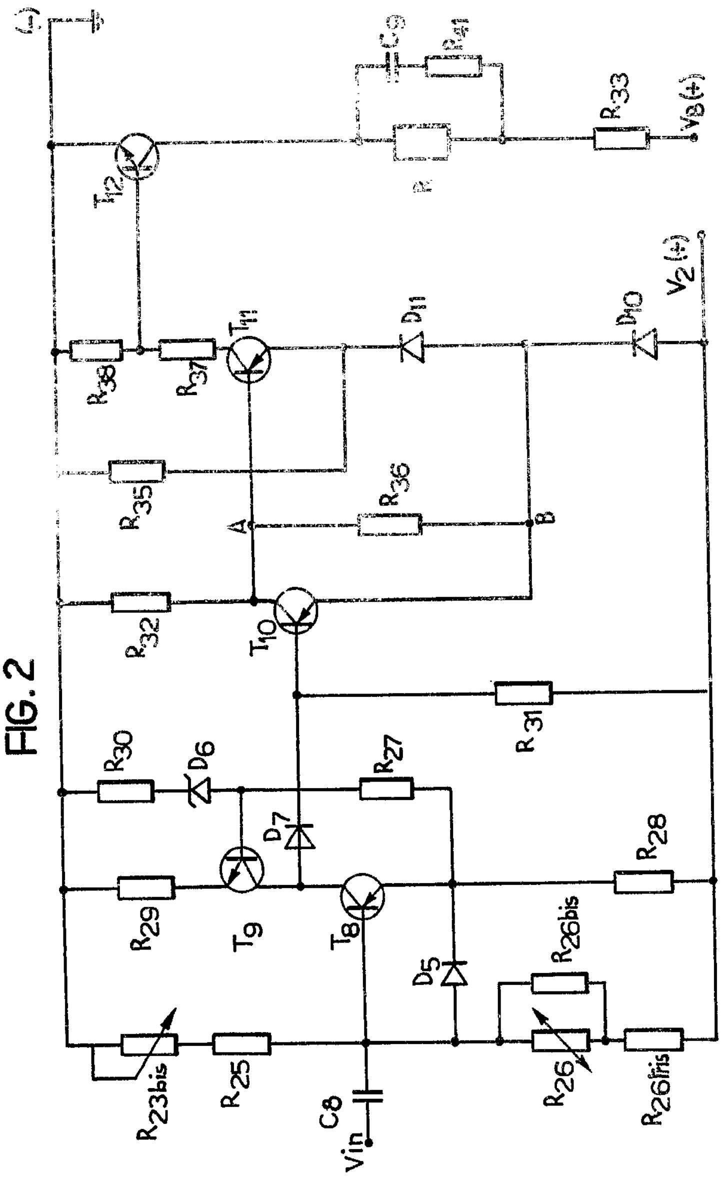
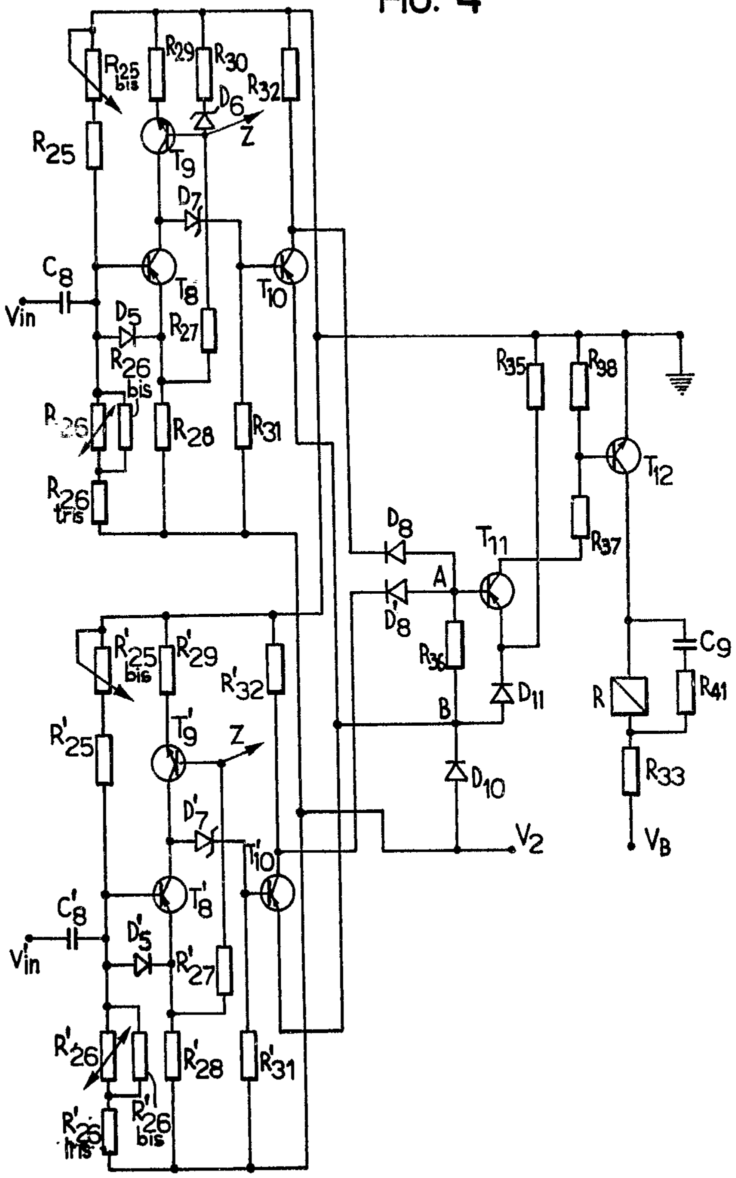


FIG. 4


R25 bis
R29
R30
D6
R32
Z
R25
T9
D7
C8
T8
T10
Vin
D5
R27
R26 bis
R26
R28
R31
R26 tris
R35
R38
T12
D8
T11
R37
A
D'8
R36
C9
D11
R
R41
B
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V2
VB
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C'8
T'8
V'in
D'5
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R'26
R'28
R'31
R'26 tris
R'26 bis