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(54) IMPROVEMENTS IN OR RELATING TO DEVICES FOR DETERMINING THE INSTANTANEOUS ANGULAR VELOCITY OF A WHEEL

(71) We, LANCIA & C. FABBRICA AUTOMOBILI TORINO S.p.A., an Italian company, of Via Vincenzo Lancia 27, Torino, Italy, do hereby declare the inventon, 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 statement:—

The present invention relates to a device for determining the instantaneous angular velocity of a wheel of a vehicle.

A device constructed in accordance with this invention can be used, for example, in producing a signal to control a solenoid valve for modulating the brake system of a vehicle, and arranged to prevent one or more wheels locking during heavy braking.

In anti-skid braking systems, in which braking modulation is effected, as a rule, in response to a signal indicating the angular velocity of one or more wheels of the vehicle, there is a problem in producing a device for indicating the instantaneous angular velocity which can be located in close proximity to a wheel, and from which there are required qualities of great sensitivity under adverse environomental conditions, while being at the same time of small bulk and low cost of manufacture.

In fact such a device has to supply an accurate signal in order to provide an efficient anti-skid action, whilst being exposed to extremely variable environmental conditions, particularly temperature which may vary from −20°C and below when starting up in the winter time, up to more than 100°C, which is reached around the hub of the wheel at a vehicle's normal operating speed in the warm season. Moreover such a device has to be of small bulk so that it can be attached to or near the hub of a wheel without requiring extensive fitting modifications to the vehicle's suspension, particularly in view of the fact that an anti-skid device represents at the present time an optional extra which is fitted upon request on to vehicles which have not been designed for such devices. Finally, the device must be economical so as not to increase the overall cost of an anti-skid device and hence the vehicle as a whole if fitted to a new vehicle.

Preferably a device of this type should not require direct drive from the wheel or the rotating axle. According to the present invention a device for producing an electric signal in dependence on the instantaneous angular velocity of a motor vehicle wheel comprises a hermetically sealed casing secured to the wheel mounting, the casing enclosing an oscillator circuit which includes two elements having a mutual inductance coupling across a recess in the casing, a blocking member secured to the wheel hub and having a plurality of equally spaced sectors which project into the said recess as the wheel rotates, thereby interrupting the mutual inductance coupling of the said elements and blocking the operation of the oscillator at a repetition frequency proportional to the angular velocity of the wheel hub.

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawings which illustrate a device applied to a braking system for motor vehicles, designed to prevent locking of one or more wheels on bracking, in which:

Figure 1 illustrates a wheel hub, with associated disc brake for the wheel, in which is housed a device constructed in accordance with the invention, with a block diagram of the outer braking modulation circuit;

Figure 2 shows an axial section of Figure 1;

Figure 3*a* and Figure 3*b* show respectively frontal and sectional views of a sensor element which forms part of the device constructed in accordance with the invention;

Figures 4*a* and 4*b* are, respectively, sectional and frontal views of a flanged ring having sectors for cooperating with the sensor element of Figures 3*a* and 3*b*;

Figure 5 is a circuit diagram of one practical embodiment of a braking modulation circuit includes a device constructed in accordance with the invention; and

Figure 6 illustrates voltage waveforms, useful in describing the functioning of the device according to the invention.

Referring now to Figures 1 and 2, which show in general the wheel hub for a motor vehicle wheel, with associated brake disc, braking calipers, bearing, etc. In Figure 1 there is also shown a simplified block diagram of an anti-skid braking circuit suitable for use with the present invention. Corresponding parts bear similar reference numerals in Figures 1 and 2.

The wheel illustrated is a rear wheel of a rear drive motor vehicle. Upon a shaft 10 there is rotatably mounted, by means of a bearing 13, a wheel hub 11 of the wheel, to which the wheel can be secured by means of bolts 11*a*. To the hub 11 there is secured a brake disc 12 by means of bolts 15, and a group of braking calipers marked, generally, 14 and arranged to cooperate with the disc 12. The bearing 13 is held in position by two shaft ring nuts 17 and 19, respectively screwed to the shaft 10 and to the hub 11.

Onto an internal thread on the outer end of the shaft 10 is screwed a plug 21 with a generally hexagonal head having a recess into which there is fixed with screws 23 a sensor 16, described in more detail below, and with which there cooperates a flanged member 22, also described in more detail below, which is mounted within an internal groove of the ring nut 19, and held in place by a circlip 25.

Referring now to Figure 1, the general operation of the anti-skid braking system will be described. The sensor 16 provides, along an insulated cable 26, a first signal to a circuit 28 which manipulates the said first signal supplying an outgoing second signal consisting of a continuous voltage inversely proportional to the angular velocity of the wheel. The sensor 16 and the circuit 28, connected by the cable 26, constitute a device constructed in accordance with the present invention.

The signal given by the circuit 28 is employed, in this embodiment of the invention, in a braking system for vehicles having means for preventing the wheels locking under heavy braking by modulating the braking action of the brake calipers. The signal from the circuit 28 is applied to a circuit 30, which provides from the annular velocity signal an acceleration signal. When a predetermined threshold value is exceeded, a solenoid valve 32 is triggered. This acts upon an actuating device 34 of the brake calipers 14, to bring about a reduction or elimination of the braking action of the brakes when a predetermined deceleration threshold is exceeded, the braking action being restored to its normal value by the solenoid valve 32 as soon as the circuit 30 indicates that deceleration has returned to below the predetermined threshold value.

One embodiment of the device designed to fulfil the functions of the circuit 30 is described in Italian patent No. 884,672 and entitled: "Modulating device for the activator of the brake of the wheels of a motor vehicle, for an anti-skid braking system".

Those parts of the illustrated system which are referenced 30, 32, 34, 36 and 14 will not be described in any further detail.

The casing of the sensor 16 comprises a box 16*a*, roughly in the form of a parallelepiped, and a cover 16*b*, both pressed preferably from a polyamide resin. The box 16*a* has a recess 18 one side of which is arched as can best be seen in Figure 1. Apertures 20 made in projections formed upon the box allow the insertion of fixing screws 23. Within the box 16*a* there is housed a small plate 25 (see Figure 3*b*) which bears an oscillating circuit described below, and which includes two coupled coils, so placed upon the plate as to be respectively positioned behind the opposite walls of the recess 18. The plate 25 is completely embedded in a filler cement, such as for example an epoxy resin. The filler cement also secures the cover 16*b* to the box 16*a* and the plate 25 with the interposition of a retainer washer 16*c*. The cover has apertures corresponding to the projections 20 of the box 16*a* by means of which the screws 23 secure the assembly in position and has, additionally, a notch 16*d* for covered cables 26 to pass through; these connect the circuit carried by the plate 25 to the outer circuits, as will be described below.

The sensor 16 is fixed with screws 23 (Figure 1) which engage into corresponding holes in the plug 21, taking up the position illustrated in Figure 2. The plug 21 has a hole through which pass the covered cables 26.

As illustrated in Figure 1, the recess 18 is intended to receive sectors 24 of a flanged annular plate 22. This plate, which is illustrated separately in Figures 4*a* and 4*b*, is of metal, for example of brass, and consists of a flange 22*a* from which extend sectors 24, which are parallel to the axis of the plate. The flanged plate 22 has been shown as having eight sectors 24, but may have a greater or smaller number, according to the intended angular velocity range of the wheel to which it is fitted, the frequency of the oscillator which forms part of the device and the required sensitivity.

Turning now to Figure 5, the circuit of the sensor device consists of an oscillator marked in the broken line rectangle, defined generally with an A. The circuit comprises an emitter amplifying transistor T_1 of the usual type, resistors R_0, R_1, R_2, a capacitor C_1 and two coils S_a, wound separately onto small ferrite rods and placed behind the opposite walls of the recess 18 (Figure 1), a few millimetres apart from each other. There being no screens between the opposite walls of the recess 18, the sensor oscillates, at a high frequency, due to the mutual inductance coupling between the coils S_a: the frequency of oscillation preferably exceeds the maximum frequency of rotation of the wheel, encountered when the latter rotates at maximum velocity by several orders of magnitude.

On rotation of the flanged annular plate 22, the sectors 24 alternately interrupt the inductive coupling between the two coils S_a, thus blocking the oscillator A. This latter will therefore have an output signal consisting of pulses of high frequency wave trains, the pulse repetition period and duration being in inverse proportion to the angular velocity of the wheel.

In Figure 6 there is shown (curve *a*) the form of the output signal of the sensor 16, when the wheel is decelerating.

Referring back to Figure 5, in the broken line rectangle B is illustrated a diagram of the circuit 28 of the device which is connected to the sensor 16 by the insulated cable 26. The circuit 28 comprises means for transforming the signal of the sensor 16 into a second signal which is related to the angular velocity of the wheel. This enables the signal to be used, for example, for triggering, after further manipulation of the signal, the solenoid valve of a brake operating device, such as components 30, 32, 34 in Figure 1. In particular, but not necessarily, this manipulation can be effected in an electronic device according to Italian patent No. 884,672 referred to above.

Thus the output signal of the sensor 16 is transmitted, by means of a capacitor C_2, to a transistor T_2 which, by means of ferrite transformer S_3, transfers alternating voltage trains to the terminals of the secondary of the transformer S_3.

These wave trains are rectified by the diode D_1 and smoothed by C_3 and R_6 and therefore emerge as continuous voltage impulses at the base-emitter junction of a transistor T_3, which, together with a transistor T_4, constitutes a Schmitt trigger.

If there is no sector 24 of the flange plate 22 between the two coils S_a, a high frequency voltage signal is transferred (as mentioned above) to transistor T_2, the direct current signal obtained at the base emitter junction of the transistor T_3 switches it on by which action the transistor T_4 switches off and charging of a capacitor C_4 can take place. This in its turn thus switches on transistor T_5 so that by virtue of a coupling capacitor C_5, the base-emitter voltage of a transistor T_6 is lowered below its cut-off voltage so that the transistor T_6 is switched off.

The presence of a sector of the flanged ring 22 between the two coils S_a prevents capacitor C_2 from sending any signal to the transistor T_2 (since the circuit A is no longer oscillating) and hence induces the transistor T_3 to switch off because there is no voltage signal at the base of transistor T_3. Transistor T_4 therefore conducts, and the state of transistor T_5 (and hence transistor T_6) is not modified, but the capacitor C_4 can now discharge through a resistor R_{13} and the parallel connected resistor R_{14} and diode D_3.

The output waveform of the Schmitt trigger composed of transistors T_3 and T_4 is shown with the letter *b* in Figure 6. The transistor T_6 returns to a conducting state automatically, as soon as the voltage of a capacitor C_5 exceeds the value of zero, which occurs within a time period determined by the discharge of capacitor C_5 through resistors R_{17}, R_{18} and the resistance of the collector-emitter junction of transistor T_5 and the value of the emitter resistor R_{19}. The response time of the circuit to the maximum switching frequency of the transistors T_5 and T_6 has been determined to be significantly less than the shortest time period between successive interruptions of the oscillator circuit by the adjacent sectors of the flanged ring 22.

Negative impulses, of variable duration, at capacitor C_4 will therefore always give output impulses of constant duration at the transistor T_6, whose load resistance is shown by R_{21} and by the parallel connection of a resistor R_{20} with the base-emitter junction of a transistor T_7. The train of impulses of constant duration is shown, for example with the wheel in a deceleration phase, in the curve "*c*" of Figure 6.

The transistor T_7 is therefore switched off every time an impulse reaches transistor T_5: at the maximum frequency of rotation of the wheel it will therefore be almost always in a non-conducting state, so as to give a minimum voltage output at the terminals of an integrating circuit comprising resistors R_{22}, R_{23}, R_{24}, and capacitors C_6, and C_7, which integrates the values of the voltage which is generated at the collector of the transistor T_7 during the conducting state of T_7, whilst, in the non-conducting state of the transistor T_7 the capacitor C_6 discharges *via* resistor R_{22} and diode D_4 and capacitor C_7 discharges *via* resistors R_{22} and R_{24} and diode D_4.

Thus for given values of the capacitance of C_6 and C_7, in combination with the resistances R_{23} and R_{24}, there is a predetermined voltage level which is constant when the switching frequency at the sensor is constant, which increases if the said frequency decreases, and decreases if the said frequency increases.

The output signal of the circuit which can be taken from the junction between the resistance R_{24} and the capacitor C_7 is thus a continuous voltage inversely proportional to the angular velocity of the wheel, and therefore, as shown in curve "d" of Figure 6, will increase when the wheel decelerates, and decrease when the wheel accelerates.

The supply voltages $V_1(+)$ and $V_2(+)$ are provided, for example, by a vehicle battery *via* a stabilised power supply device with transistors of the conventional type, in order to obtain a high level of voltage stability.

The response of this device can be very rapid, for example, in the order of only a few micro-seconds, and the signal supplied can be exact and constant partly because of the stabilised supply, and partly because that part of the device, that is, the sensor, which is most exposed to wide variations of temperature and to the most varied environmental conditions, is enclosed within an hermetic shell. Moreover, variations of the electrical parameters of the oscillator contained in this hermetic shell, such as to vary the frequency of oscillation, do not affect the accuracy of the signal because only the variations connected with the angular speed of the wheel are exclusively controlled by the passage of the sectors of the flanged plate 22 in the recess in the sensor. The vehicle wheel or its axle does not operate directly, mechanical devices such as switches, and moreover the recess in the shell of the sensor 16 may be of such width as to allow relatively wide misalignment between the plate and the sensor so that mass production techniques can be employed in their manufacture. In fact, the whole device lends itself to mass production at low cost of manufacture and requires practically no adjustment after the original setting carried out upon initial prototypes.

Moreover, it will be apparent to experts in this field that a number of variants of the device, particularly in respect to the manipulatory means of the signal supplied by the sensor are possible. In particular the Schmitt trigger comprising the transistors T_3 and T_4 could be replaced by any other suitable bistable multivibrator. Some parts of the described apparatus may be left out, for example the amplifier comprising the transistor T_2, may be omitted where the signal given by the sensor is strong enough for direct manipulation without amplification.

Moreover it will be apparent that the output signal of the device can be in a different form from a continuous voltage inversely proportional to the angular velocity of the rotating axle as described above. In particular, the said continuous voltage could be directly proportional to the velocity, or the signal may be utilised in one of the intermediate forms which it assumes in the various stages of the converting means which have been described. More particularly, one directly usable form of the signal can be illustrated in the wave form "*c*" of Figure 6, in which there is a sequence of impulses of constant duration having a repetition frequency proportional to the angular velocity of the wheel or axle and this form of output signal would lend itself, for example, to utilisation in an impulse meter of any type, for example in uses such as speedometers, etc.

It can also be envisaged that the signal at the output of the Schmitt trigger, that is in the form shown by the line "b" of Figure 6, may be taken off and used directly.

WHAT WE CLAIM IS:—

1. A device for producing an electric signal in depedence on the instantaneous angular velocity of a motor vehicle wheel comprising an hermetically sealed casing secured to the wheel mounting, the casing enclosing an oscillator circuit which includes two elements having a mutual inductance coupling across a recess in the casing, a blocking member secured to the wheel hub and having a plurality of equally spaced sectors which project into the said recess as the wheel rotates, thereby interrupting the mutual inductance coupling of the said elements and blocking the operation of the oscillator at a repetition frequency proportional to the angular velocity of the wheel hub.

2. A device as claimed in Claim 1 in which the wheel mounting includes a hollow shaft and the hermetically sealed casing is secured to one end of the shaft by means of a screw-threaded member attached to the end of the shaft.

3. A device as claimed in Claim 2 having leads for conveying the output signals to a circuit for processing the signals, which leads pass through the screw-threaded member into the hollow shaft.

4. A device as claimed in any preceding claim in which the sectors of the said member secured to the wheel hub are of metal.

5. A device as claimed in any preceding claim in which the said blocking member is secured within an annular recess in the wheel hub by means of a circlip.

6. A device for producing an electric signal in dependence on the instantaneous angular velocity of a wheel substantially as hereinbefore described with reference to the accompanying drawings.

7. An anti-skid braking system for a motor vehicle including a device as claimed in any preceding claim.

FORRESTER, KETLEY & CO.
Chartered Patent Agents
Jessel Chambers,
88/90 Chancery Lane,
London, W.C.2.
—and—
Rutland House,
Edmund Street,
Birmingham 3,
Agents for the Applicants

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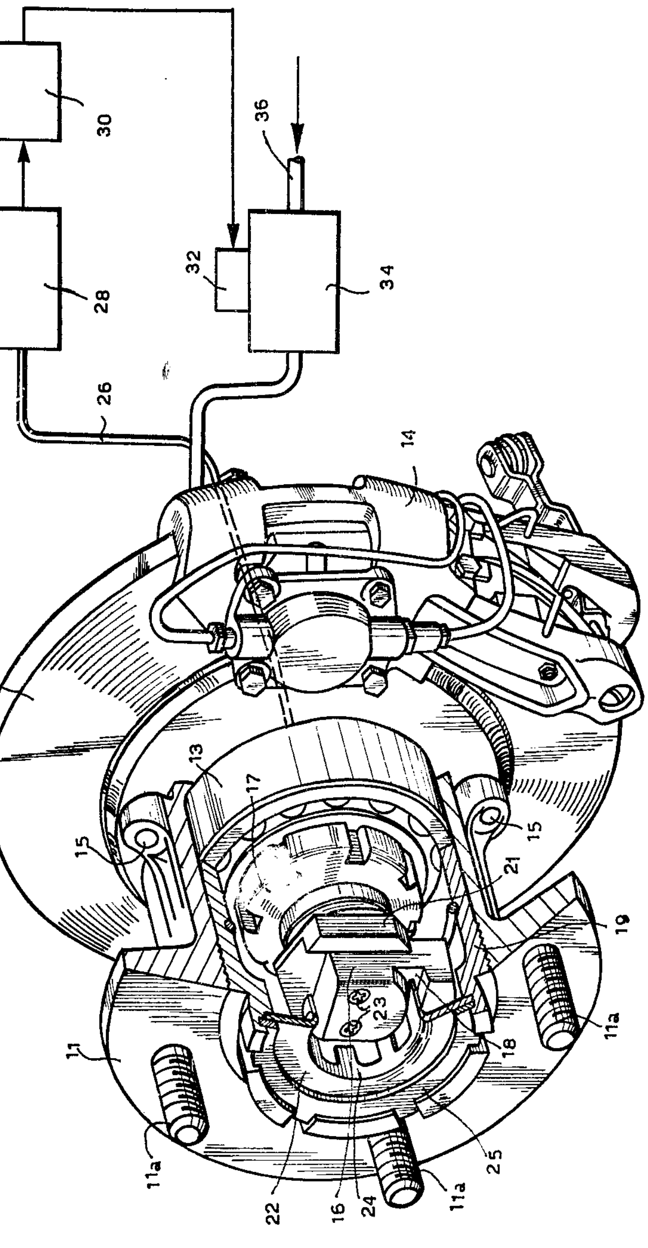
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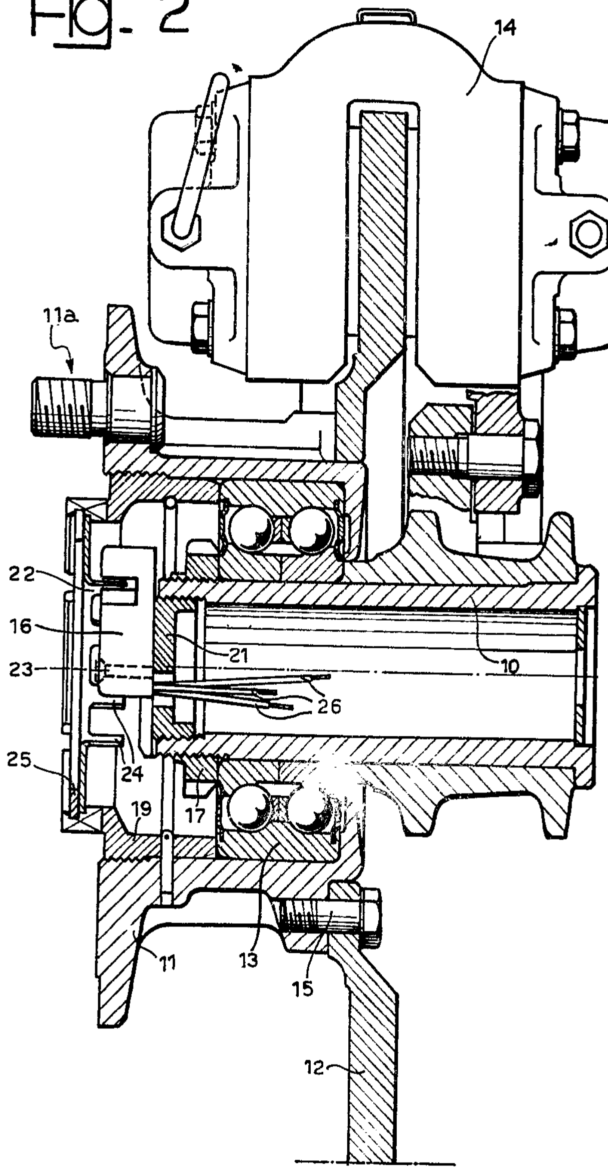
Fig.1

Fig. 2



1289899 COMPLETE SPECIFICATION

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

Sheet 3

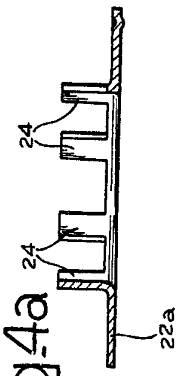


Fig.4a

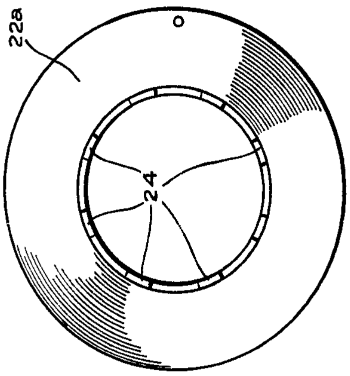


Fig.4b

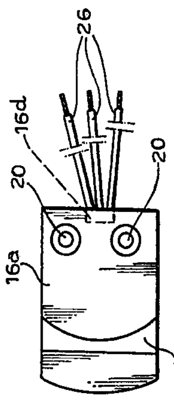


Fig.3a

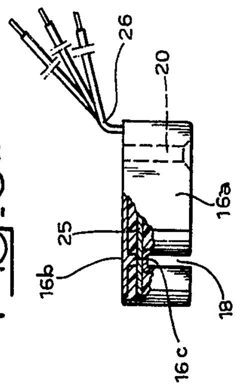


Fig.3b

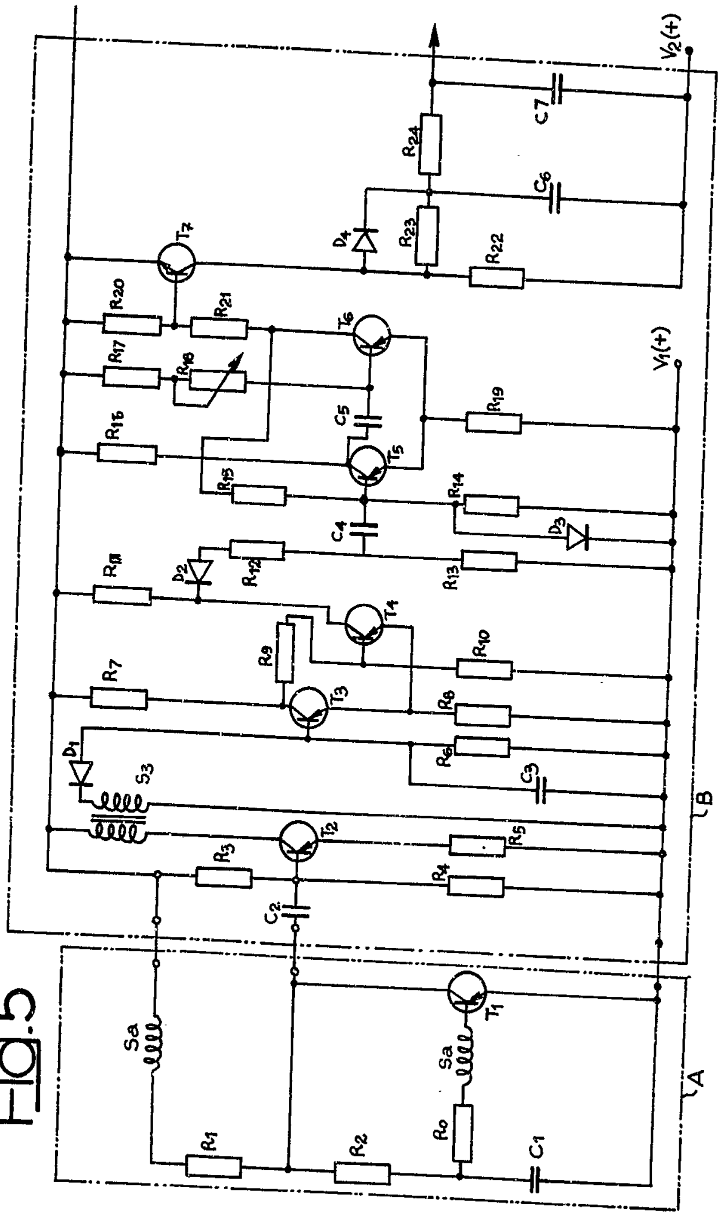

V2(+)
V1(+)
C7
C6
R24
R23
R22
D4
T7
R20
R21
T6
R17
R18
C5
R19
R16
T5
R15
R14
C4
D3
R11
D2
R12
R13
T4
R9
R10
R7
T3
R8
D1
R6
C3
S3
T2
R5
R3
R4
C2
B
T1
Sa
R1
R2
R0
C1
A

Fig.5

Fig. 6