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**Method of controlling a motor**

The invention proceeds from a method according to the preamble of Claim 1. It is known to feed motors not with a DC voltage of variable magnitude but with a pulse-width-modulated voltage of constant amplitude, the pulse-width modulation (PWM) determining the respective torque or the rate of rotation. This operation is also designated chopper operation. The frequency of the pulse-conduction-modulated [sic] pulses in this case lies above the audible range, on the one hand in order to avoid audibility of the motor control and, on the other hand, to ensure that, in spite of the pulsed control, there is virtually a direct current flowing in the motor winding as a result of the integrating action, the magnitude of the direct current being determined by the PWM.

To initiate a braking process of the motor or to reverse the direction of rotation it is known in each case to reverse the polarity of the motor windings within the circuit, so that the motor is suddenly driven in the opposite direction of rotation. The motor then initially runs further in its previous direction of rotation, is braked in the process and then assumes the opposite direction of rotation. In this type of braking the following difficulty arises.

The ends of the motor windings are connected to the operating voltage or to earth via protective diodes. The diodes serve for the purpose of protecting the connected semiconductor components from destruction by voltage peaks on the motor windings. If, then, at the beginning of a braking process a motor winding has its polarity reversed, it is possible as a result of the effect of the said diodes, irrespective of the drive, for a high current to flow, which is given by the generator voltage or EMF generated by the motor and the resistance of the motor winding. This current acts as a braking current because of the rotation of the motor, that is to say as a result of the relative motion between the motor windings and the permanent magnets. Since this current

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cannot be less than the said value, in many cases the braking effect can be too great. If, for example, the motor is the capstan motor in a video recorder and the braking of the tape advance is carried out too quickly, the formation of loops of the magnetic tape can occur as a result of the inertia of the overrunning unwind disc.

The invention is based on the object of providing a method of controlling a motor with a pulse-width-modulated drive, which method enables a defined braking effect. This object is achieved by the invention specified in Claim 1. Advantageous developments of the invention are specified in the subclaims.

In the case of the invention, therefore, for the initiation of the braking process it is not a steady-state reversal of polarity of the motor winding relative to the feed terminals which is carried out but an intermittent reversal of polarity. During a period which is preferably equal to the period of the pulse-width-modulated voltage, the said reversal of polarity of the winding is therefore carried out for a specific time, whereas this reversal of polarity is cancelled for the remaining time of the period. By selecting the pulse/pause ratio in this intermittent reversal of polarity of the winding, the braking effect can be changed within wide limits. No change in the frequency or the amplitude of the actual pulse-width-modulated operating voltage for the motor is in this case necessary.

It is preferable if a first manipulated variable indicating the desired direction of rotation and a second manipulated variable indicating the actual direction of rotation are compared and a third manipulated variable, which occurs if there is a deviation, is derived therefrom, the said third manipulated variable triggering the intermittent reversal of polarity of the winding. The ratio of the duration of the said reversal of polarity to the entire period of the intermittent reversal of polarity can preferably be varied between the values 0 and 1. The width-modulated pulses and the switching voltage for the intermittent reversal of polarity are



preferably derived from the same pulse voltage. In the event of coincidence between the desired and actual direction of rotation, the motor is fed only by the pulse-width-modulated pulses in the direction of constant direction of rotation and, in the event of non-coincidence between desired and actual direction of rotation, the motor is alternately fed in the direction of the opposite direction of rotation. The second manipulated variable indicating the actual direction of rotation of the [sic] is preferably determined by sensors assigned to the motor. The information about the desired braking effect is preferably derived via sensors from the motor and/or from typical motor data.

The invention is explained in more detail below with reference to the drawing, in which:

Figure 1 shows a basic circuit diagram for the method according to the invention,

Figure 2 shows a diagram for the currents produced in the case of different pulse/pause ratio of the intermittent reversal of polarity,

Figure 3 shows a basic block diagram of the method according to the invention and

Figures 4 - 11 show a logic circuit for various operating states.

In the description, the symbols used have the following meaning:

UB Constant operating voltage for the motor feed
UG EMF induced in the motor winding
IM Current through the motor
RM Resistance of the motor winding
T Period of the pulse-width-modulated voltage and of the intermittent reversal of polarity
ton Duration of the reversal of polarity during the period of the intermittent reversal of polarity
P = ton/T

In Figure 1, the operating voltage UB is converted into a pulse-width-modulated pulse voltage using the switch S1. S1 is actuated by the control circuit S by the pulse-width-modulated pulse voltage 6.



The pulse-width-modulated pulse voltage which is produced by this means from the output of S1 passes via the changeover switches S2, S3 to the motor 7, for which the generator G, producing the induced voltage U_G or EMF, and the resistance R_M of the motor winding are shown. To initiate a braking process, the switches S2, S3 are changed over into the other position by means of the control circuit S. That means that the winding of the motor 7 has its polarity reversed in relation to the feeding voltage. However, this reversal of polarity is not always carried out as a steady-state process but can also be carried out intermittently, as is shown by the switching voltage 8. The on-time t_{on} of the reversal of polarity by the switches S2, S3 in relation to the period T of the intermittent reversal of polarity determines the braking torque. The value of t_{on} and hence the braking torque are determined by a control circuit S. The latter obtains additional information about mechanical or electrical motor values from sensors via the terminal 9.

Referring to Figure 2, it will be explained with reference to equations how a respectively desired braking effect can be achieved by altering the duty ratio $P = t_{on}/T$. Equation A shows the motor current i_M , to be specific on the one hand for the time t_{on} and on the other hand for the subsequent pause $T - t_{on}$. Equation A is thus generally valid. Equation B shows the resulting current at $P = 0$, equation C for a specific P, equation D for another P and equation E for the other limiting value $P = 1$. Since the current i_M [sic] is integrated over the entire period T, in each case the current value integrated over the times t_{on} and $T - t_{on}$ governs the braking effect. It can be seen that this value can be very small or zero for specific values between $P = 0$ and $P = 1$. If, for example, the negative expression in the equations becomes $-U_G/R_M$, the integrated current value is virtually zero. Therefore, the respectively desired braking effect can be set by selecting P between 0 and 1, that is to say between no reversal of polarity being carried out at all and continuous reversal of polarity.

Figure 3 shows a simplified block diagram for implementing the method according to the invention. A logic circuit 5, which has three inputs a, b, c, is shown. The pulse-width-modulated pulse voltage, as is present at the output of S1 in Figure 1, is fed to the input a. The first manipulated variable indicating the desired direction of rotation is fed to the input b and the second manipulated variable indicating the actual direction of rotation is fed to the input c. The circuit 5 has two outputs d and e. The output d controls the reversal of polarity of the winding via the switches S2, S3. The output e carries the actual pulse-width-modulated feed voltage, as is present at the output of S1 in Figure 1.

In Figures 4 - 11, the letters a - e show which voltages are present at the corresponding inputs a, b, c, according to Figures 5, 7, 9, 10 and at the outputs d, e in the Figures 4, 6, 8, 10.

Figures 4, 5 show one possible practical implementation of the circuit 5 according to Figure 3. The circuit 5 contains a first EXOR gate 1, a second EXOR gate 2, an AND gate 3 and an OR gate 4. Figure 4 applies for the case in which the desired direction of rotation and actual direction of rotation coincide, that is to say both manipulated variables at the inputs b, c have the value 0. The value 0 then appears at the output d, so that the direction of rotation is not switched over in the manner desired. The actual pulse-width-modulated voltage for feeding the motor is present at the output e. This is the case in which the motor is running in its desired direction of rotation and hence a reversal of polarity of a winding is not intended to be carried out.

Figures 6, 7 show the same relationships for steady operation with coincidence between the intended direction and actual direction, but for the other direction of rotation.

Figures 8, 9 show the case in which the manipulated variable at the input b for the desired direction of rotation and the manipulated variable at the



input c for the actual direction of rotation differ from each other. The output e, which intrinsically carries the pulse-width-modulated voltage in Figures 4 - 7, now remains at 1. This means firstly that the full operating
5 voltage UB is continuously present at the output of S1 in Figure 1. The output d, which effects the reversal of polarity of the motor winding, now corresponds to the pulse-width-modulated voltage at the input a. This now means that the motor winding has its polarity reversed
10 intermittently, corresponding to the value P according to Figure 2.

Figures 10, 11 apply in a corresponding manner for the case in which the desired direction of rotation and the actual direction of rotation in each case have
15 the opposite value to Figures 8, 9. Otherwise, the effect is similar to that in Figures 8, 9, with the difference that the pulse voltage at the output d, which effects the reversal of polarity of the motor winding, is now rotated by 180° in comparison with Figure 9. It can be seen that
20 the pulse voltage for feeding the motor, on the one hand, and the pulse voltage for the reversal of polarity of the motor winding for the braking process are derived from the same input voltage at the terminal a. The actual power supply to the motor comes continuously from the
25 output e of the circuit 5, whereas the output d controls the reversal of polarity of the winding corresponding to the switches S2, S3 in Figure 1.

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Patent claims



1. Method of controlling a motor, in which a motor winding is fed with pulse-width-modulated pulse [sic] (a) and, in order to initiate a braking process, the winding has its polarity reversed, characterized in that intermittent reversal of the polarity of the winding is effected for time intervals (t_{on}) which are separated by pauses ($T-t_{on}$) and whose duration depends on the respectively desired braking effect.
2. Method according to Claim 1, characterized in that a first manipulated variable (b) indicating the desired direction of rotation and a second manipulated variable (c) indicating the actual direction of rotation are compared and a third manipulated variable (d), which occurs if there is a deviation, triggers the intermittent reversal of polarity of the winding.
3. Method according to Claim 1, characterized in that the ratio (P) of the duration (t_{on}) of the reversal of polarity to the period (T) of reversal of polarity and pause can be varied between 0 and 1.
4. Method according to Claim 1, characterized in that the pulse-width-modulated pulses (e) and a switching voltage (d) for the intermittent reversal of polarity are derived from the same pulse voltage (a).
5. Method according to Claim 1, characterized in that, in the event of coincidence between the desired and actual direction of rotation, the motor (7) is fed only by the pulse-width-modulated pulses (e) in the direction of constant direction of rotation and, in the event of non-coincidence between desired and actual direction of rotation, the motor (7) is alternately fed in the direction of the opposite direction of rotation.
6. Method according to Claim 1, characterized in that the frequency of the pulse-width-modulated pulses (a, e) lies above the audible range.
7. Method according to Claim 1, characterized in that the second manipulated variable (c), indicating the actual direction of rotation, is determined by sensors



assigned to the motor (7).

8. Method according to Claim 1, characterized in that the information about the desired braking effect is derived via sensors from the motor (7) and/or from
5 typical motor data.

9. Circuit for a method according to Claim 2, characterized in that the circuit is designed as a logic circuit (5), which has three inputs (a, b, c) for the pulse-width-modulated pulses (a), for the first
10 manipulated variable (b) and for the second manipulated variable (c), and two outputs (d, e) for the reversal of polarity of the winding and for the motor drive (Figure 3).

10. Circuit according to Claim 9, characterized in that a terminal (a) carrying the pulse-width-modulated
15 pulses is connected to the first inputs of an AND gate (3) and of an OR gate (4), a terminal (b) carrying the first manipulated variable is connected to the first inputs of a first EXOR gate (1) and of a second EXOR gate (2), a terminal (c) carrying the second manipulated
20 variable is connected to the second input of the first EXOR gate (1), in that the output of the first EXOR gate (1) is connected to the second inputs of the AND gate (3) and of the OR gate (4) and the output of the AND gate (3) is connected to the second input of the second EXOR gate
25 (2), and in that the output of the OR gate (4) supplies the pulses for driving the motor (7) and the output (d) of the second EXOR gate (2) supplies a switching voltage for reversing the polarity of the winding.

30 11. Method according to Claim 1, characterized in that pulses of constant amplitude do not need to be used for driving.

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Abstract

Method of controlling a motor

It is known to control motors in so-called chopper operation with a pulse-width modulated voltage of constant amplitude. For the purposes of braking or reversal of the direction of rotation, a motor winding has its polarity changed in each case. It has been shown that in many other applications, for example in the case of a capstan motor of a video recorder, the braking is carried out too rapidly. It is the object to provide a method using chopper operation which enables a defined braking effect for the motor.

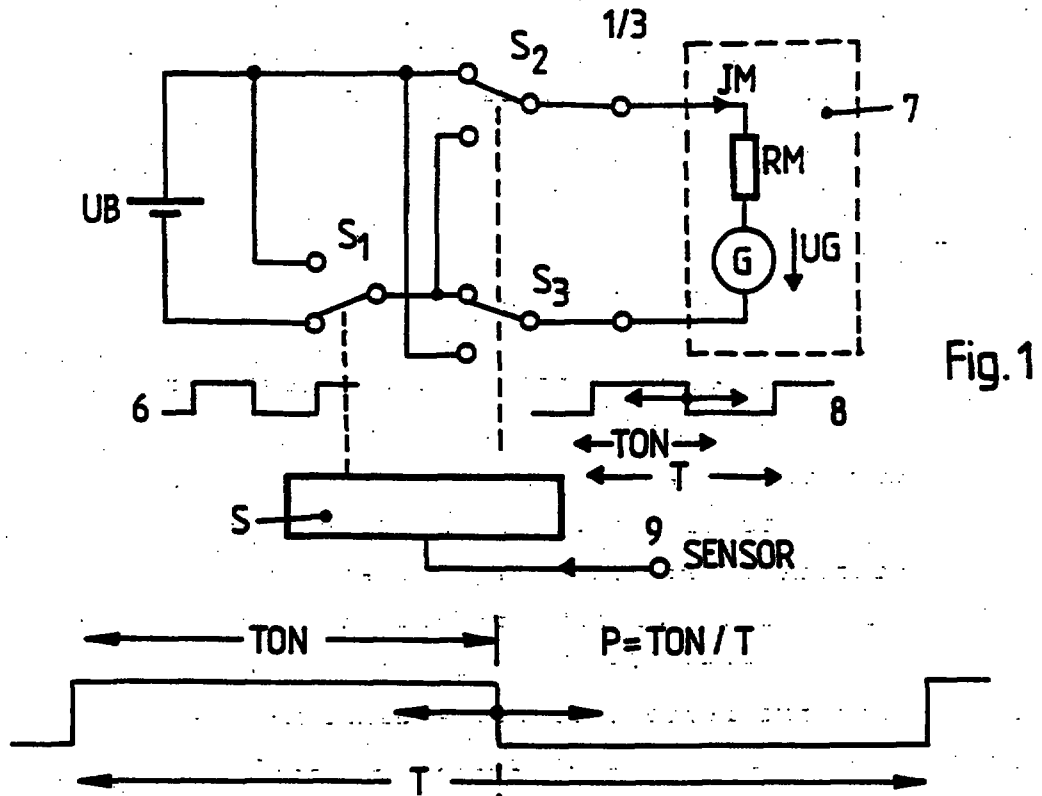
An intermittent reversal of polarity of the winding is carried out the [sic] time intervals separated by pauses and whose duration depends on the respectively desired braking effect.

In particular for the capstan motor in a video recorder

Fig. 1

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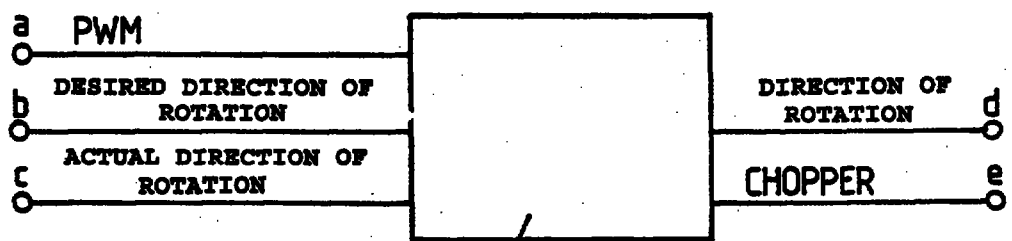
$$IM = \frac{P \cdot UB}{RM} + \frac{UG}{RM}$$

$$IM = \frac{UG}{RM}$$

$$I_M = 2 \cdot \frac{U_G}{R_M}$$

$$IM = 3 \cdot \frac{UG}{RM}$$

$$I_M = \frac{U_B}{R_M} + \frac{U_G}{R_M}$$



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Fig.3

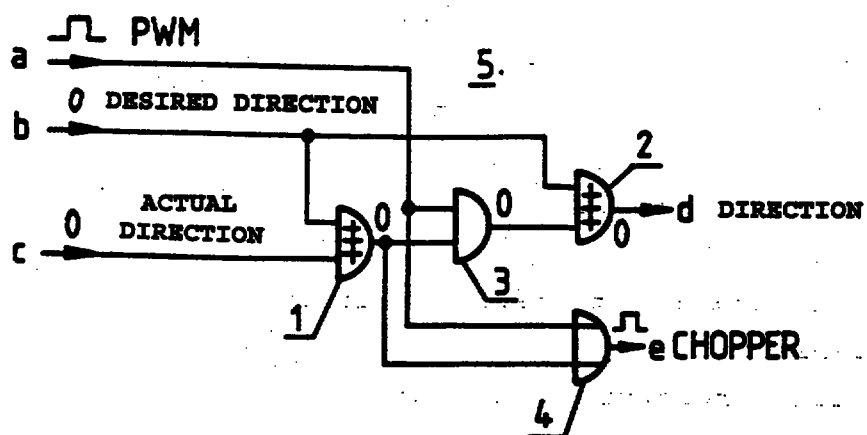


Fig. 4

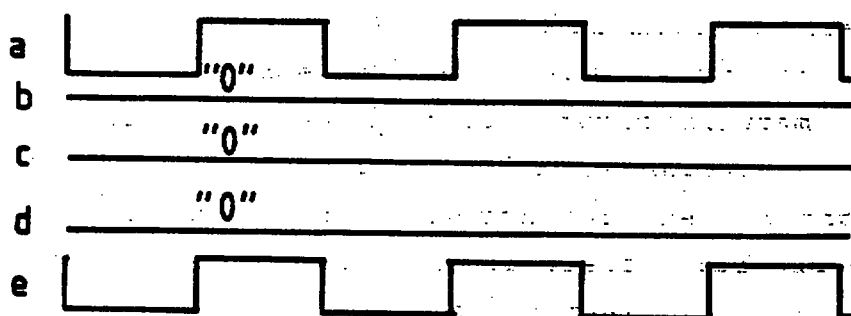


Fig. 5

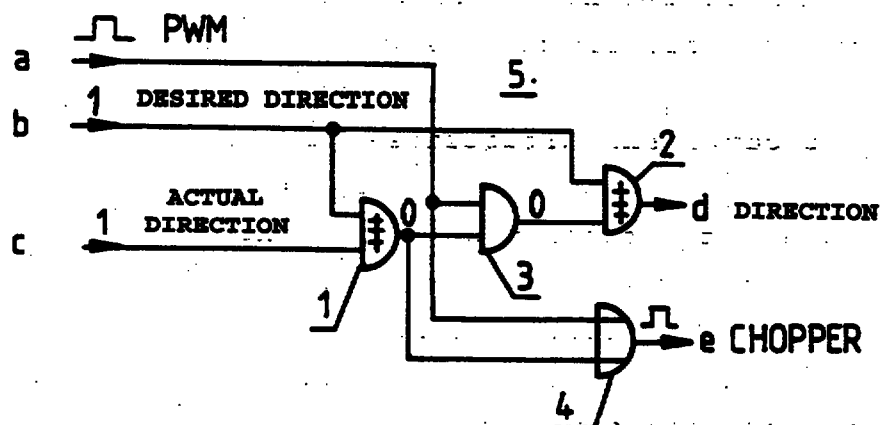


Fig. 6

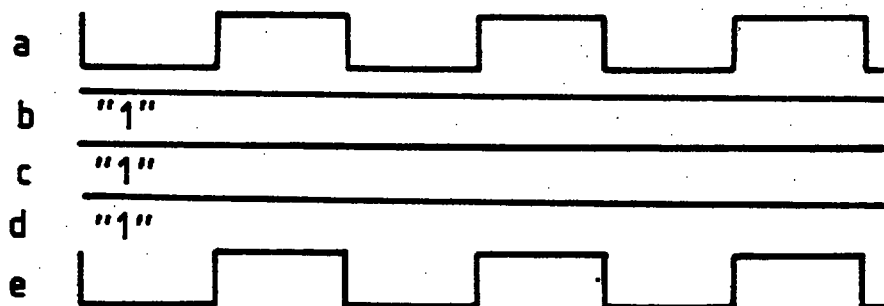


Fig. 7



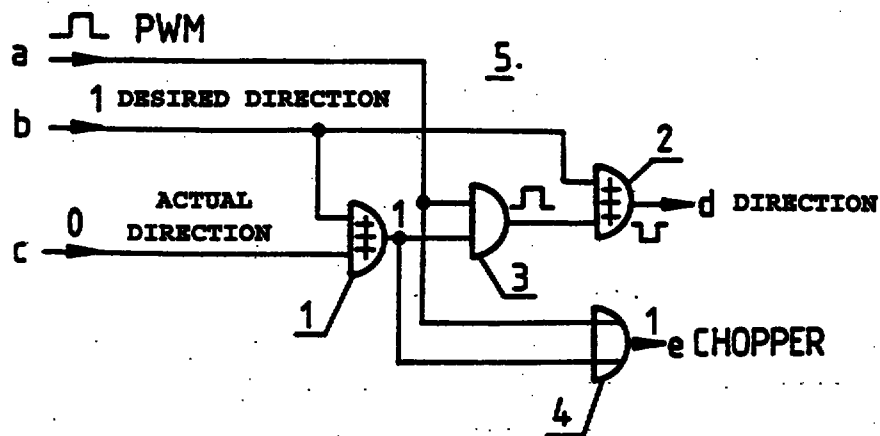


Fig.8

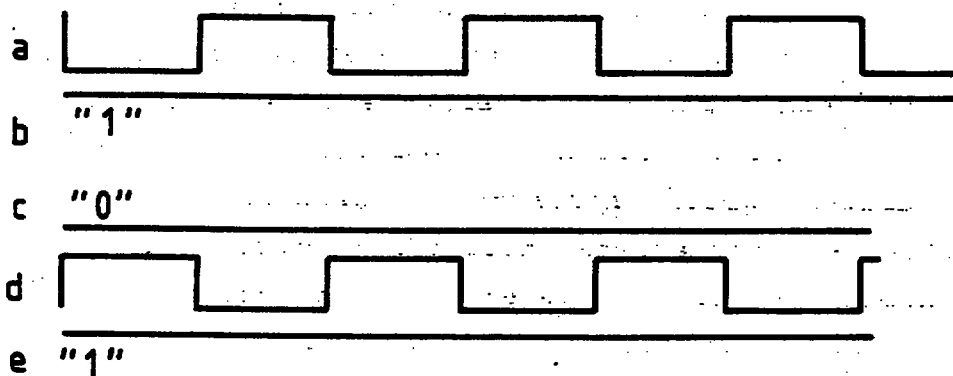


Fig.9

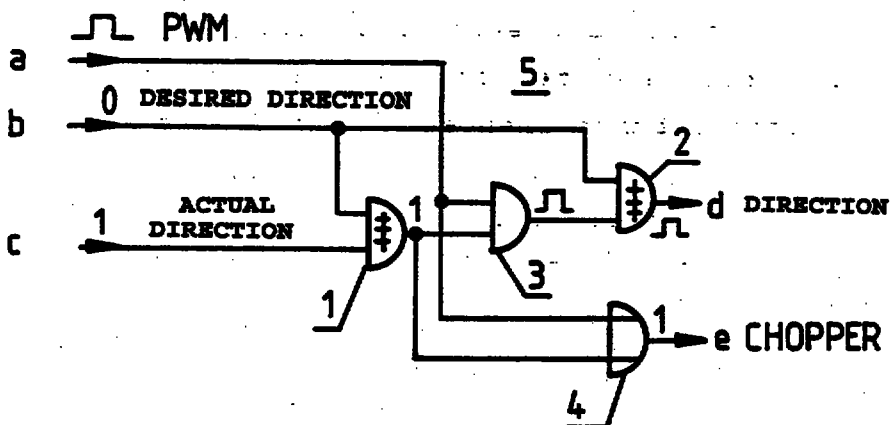


Fig.10

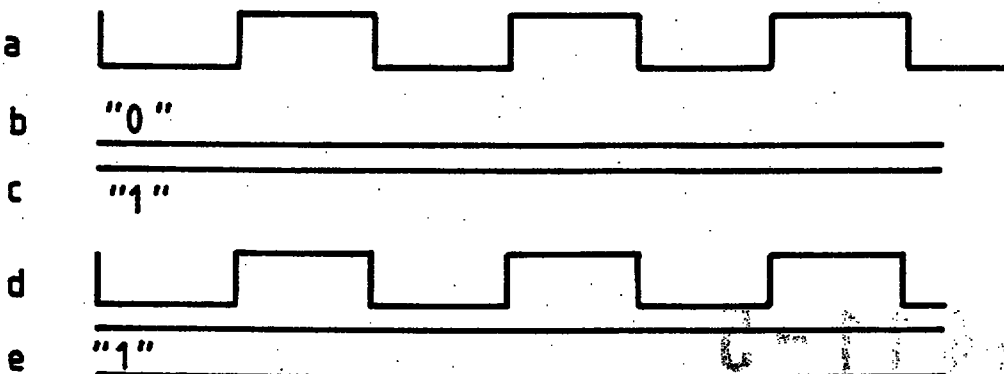


Fig.11

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☒ Claim(s) : paged 7... to paged 8...
☒ Drawing(s) : paged 1/3 to paged 3/3
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Method of controlling a motor

The invention proceeds from a method according to the preamble of Claim 1. It is known to feed motors not with a DC voltage of variable magnitude but with a pulse-width-modulated voltage of constant amplitude, the pulse-width modulation (PWM) determining the respective torque or the rate of rotation. This operation is also designated chopper operation. The frequency of the pulse-conduction-modulated [sic] pulses in this case lies above the audible range, on the one hand in order to avoid audibility of the motor control and, on the other hand, to ensure that, in spite of the pulsed control, there is virtually a direct current flowing in the motor winding as a result of the integrating action, the magnitude of the direct current being determined by the PWM.

To initiate a braking process of the motor or to reverse the direction of rotation it is known in each case to reverse the polarity of the motor windings within the circuit, so that the motor is suddenly driven in the opposite direction of rotation. The motor then initially runs further in its previous direction of rotation, is braked in the process and then assumes the opposite direction of rotation. In this type of braking the following difficulty arises.

The ends of the motor windings are connected to the operating voltage or to earth via protective diodes. The diodes serve for the purpose of protecting the connected semiconductor components from destruction by voltage peaks on the motor windings. If, then, at the beginning of a braking process a motor winding has its polarity reversed, it is possible as a result of the effect of the said diodes, irrespective of the drive, for a high current to flow, which is given by the generator voltage or EMF generated by the motor and the resistance of the motor winding. This current acts as a braking current because of the rotation of the motor, that is to say as a result of the relative motion between the motor windings and the permanent magnets. Since this current

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cannot be less than the said value, in many cases the braking effect can be too great. If, for example, the motor is the capstan motor in a video recorder and the braking of the tape advance is carried out too quickly, the formation of loops of the magnetic tape can occur as a result of the inertia of the overrunning unwind disc.

The invention is based on the object of providing a method of controlling a motor with a pulse-width-modulated drive, which method enables a defined braking effect. This object is achieved by the invention specified in Claim 1. Advantageous developments of the invention are specified in the subclaims.

In the case of the invention, therefore, for the initiation of the braking process it is not a steady-state reversal of polarity of the motor winding relative to the feed terminals which is carried out but an intermittent reversal of polarity. During a period which is preferably equal to the period of the pulse-width-modulated voltage, the said reversal of polarity of the winding is therefore carried out for a specific time, whereas this reversal of polarity is cancelled for the remaining time of the period. By selecting the pulse/pause ratio in this intermittent reversal of polarity of the winding, the braking effect can be changed within wide limits. No change in the frequency or the amplitude of the actual pulse-width-modulated operating voltage for the motor is in this case necessary.

It is preferable if a first manipulated variable indicating the desired direction of rotation and a second manipulated variable indicating the actual direction of rotation are compared and a third manipulated variable, which occurs if there is a deviation, is derived therefrom, the said third manipulated variable triggering the intermittent reversal of polarity of the winding. The ratio of the duration of the said reversal of polarity to the entire period of the intermittent reversal of polarity can preferably be varied between the values 0 and 1. The width-modulated pulses and the switching voltage for the intermittent reversal of polarity are



preferably derived from the same pulse voltage. In the event of coincidence between the desired and actual direction of rotation, the motor is fed only by the pulse-width-modulated pulses in the direction of constant direction of rotation and, in the event of non-coincidence between desired and actual direction of rotation, the motor is alternately fed in the direction of the opposite direction of rotation. The second manipulated variable indicating the actual direction of rotation of the [sic] is preferably determined by sensors assigned to the motor. The information about the desired braking effect is preferably derived via sensors from the motor and/or from typical motor data.

The invention is explained in more detail below with reference to the drawing, in which:

Figure 1 shows a basic circuit diagram for the method according to the invention,

Figure 2 shows a diagram for the currents produced in the case of different pulse/pause ratio of the intermittent reversal of polarity,

Figure 3 shows a basic block diagram of the method according to the invention and

Figures 4 - 11 show a logic circuit for various operating states.

In the description, the symbols used have the following meaning:

UB Constant operating voltage for the motor feed

UG EMF induced in the motor winding

IM Current through the motor

RM Resistance of the motor winding

T Period of the pulse-width-modulated voltage and of the intermittent reversal of polarity

ton Duration of the reversal of polarity during the period of the intermittent reversal of polarity

$P = \text{ton}/T$

In Figure 1, the operating voltage UB is converted into a pulse-width-modulated pulse voltage using the switch S1. S1 is actuated by the control circuit S by the pulse-width-modulated pulse voltage 6.



The pulse-width-modulated pulse voltage which is produced by this means from the output of S1 passes via the changeover switches S2, S3 to the motor 7, for which the generator G, producing the induced voltage UG or EMF, and the resistance RM of the motor winding are shown. To initiate a braking process, the switches S2, S3 are changed over into the other position by means of the control circuit S. That means that the winding of the motor 7 has its polarity reversed in relation to the feeding voltage. However, this reversal of polarity is not always carried out as a steady-state process but can also be carried out intermittently, as is shown by the switching voltage 8. The on-time t_{on} of the reversal of polarity by the switches S2, S3 in relation to the period T of the intermittent reversal of polarity determines the braking torque. The value of t_{on} and hence the braking torque are determined by a control circuit S. The latter obtains additional information about mechanical or electrical motor values from sensors via the terminal 9.

Referring to Figure 2, it will be explained with reference to equations how a respectively desired braking effect can be achieved by altering the duty ratio $P = t_{on}/T$. Equation A shows the motor current i_M , to be specific on the one hand for the time t_{on} and on the other hand for the subsequent pause $T - t_{on}$. Equation A is thus generally valid. Equation B shows the resulting current at $P = 0$, equation C for a specific P, equation D for another P and equation E for the other limiting value $P = 1$. Since the current i_M [sic] is integrated over the entire period T, in each case the current value integrated over the times t_{on} and $T - t_{on}$ governs the braking effect. It can be seen that this value can be very small or zero for specific values between $P = 0$ and $P = 1$. If, for example, the negative expression in the equations becomes $= U_G/R_M$, the integrated current value is virtually zero. Therefore, the respectively desired braking effect can be set by selecting P between 0 and 1, that is to say between no reversal of polarity being carried out at all and continuous reversal of polarity.



Figure 3 shows a simplified block diagram for implementing the method according to the invention. A logic circuit 5, which has three inputs a, b, c, is shown. The pulse-width-modulated pulse voltage, as is present at the output of S1 in Figure 1, is fed to the input a. The first manipulated variable indicating the desired direction of rotation is fed to the input b and the second manipulated variable indicating the actual direction of rotation is fed to the input c. The circuit 5 has two outputs d and e. The output d controls the reversal of polarity of the winding via the switches S2, S3. The output e carries the actual pulse-width-modulated feed voltage, as is present at the output of S1 in Figure 1.

In Figures 4 - 11, the letters a - e show which voltages are present at the corresponding inputs a, b, c, according to Figures 5, 7, 9, 10 and at the outputs d, e in the Figures 4, 6, 8, 10.

Figures 4, 5 show one possible practical implementation of the circuit 5 according to Figure 3. The circuit 5 contains a first EXOR gate 1, a second EXOR gate 2, an AND gate 3 and an OR gate 4. Figure 4 applies for the case in which the desired direction of rotation and actual direction of rotation coincide, that is to say both manipulated variables at the inputs b, c have the value 0. The value 0 then appears at the output d, so that the direction of rotation is not switched over in the manner desired. The actual pulse-width-modulated voltage for feeding the motor is present at the output e. This is the case in which the motor is running in its desired direction of rotation and hence a reversal of polarity of a winding is not intended to be carried out.

Figures 6, 7 show the same relationships for steady operation with coincidence between the intended direction and actual direction, but for the other direction of rotation.

Figures 8, 9 show the case in which the manipulated variable at the input b for the desired direction of rotation and the manipulated variable at the



input c for the actual direction of rotation differ from each other. The output e, which intrinsically carries the pulse-width-modulated voltage in Figures 4 - 7, now remains at 1. This means firstly that the full operating voltage UB is continuously present at the output of S1 in Figure 1. The output d, which effects the reversal of polarity of the motor winding, now corresponds to the pulse-width-modulated voltage at the input a. This now means that the motor winding has its polarity reversed intermittently, corresponding to the value P according to Figure 2.

Figures 10, 11 apply in a corresponding manner for the case in which the desired direction of rotation and the actual direction of rotation in each case have the opposite value to Figures 8, 9. Otherwise, the effect is similar to that in Figures 8, 9, with the difference that the pulse voltage at the output d, which effects the reversal of polarity of the motor winding, is now rotated by 180° in comparison with Figure 9. It can be seen that the pulse voltage for feeding the motor, on the one hand, and the pulse voltage for the reversal of polarity of the motor winding for the braking process are derived from the same input voltage at the terminal a. The actual power supply to the motor comes continuously from the output e of the circuit 5, whereas the output d controls the reversal of polarity of the winding corresponding to the switches S2, S3 in Figure 1.

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Patent claims

1. Method of controlling a motor, in which a motor winding is fed with pulse-width-modulated pulse [sic] (a) and, in order to initiate a braking process, the winding has its polarity reversed, characterized in that intermittent reversal of the polarity of the winding is effected for time intervals (ton) which are separated by pauses (T-ton) and whose duration depends on the respectively desired braking effect.
2. Method according to Claim 1, characterized in that a first manipulated variable (b) indicating the desired direction of rotation and a second manipulated variable (c) indicating the actual direction of rotation are compared and a third manipulated variable (d), which occurs if there is a deviation, triggers the intermittent reversal of polarity of the winding.
3. Method according to Claim 1, characterized in that the ratio (P) of the duration (ton) of the reversal of polarity to the period (T) of reversal of polarity and pause can be varied between 0 and 1.
4. Method according to Claim 1, characterized in that the pulse-width-modulated pulses (e) and a switching voltage (d) for the intermittent reversal of polarity are derived from the same pulse voltage (a).
5. Method according to Claim 1, characterized in that, in the event of coincidence between the desired and actual direction of rotation, the motor (7) is fed only by the pulse-width-modulated pulses (e) in the direction of constant direction of rotation and, in the event of non-coincidence between desired and actual direction of rotation, the motor (7) is alternately fed in the direction of the opposite direction of rotation.
6. Method according to Claim 1, characterized in that the frequency of the pulse-width-modulated pulses (a, e) lies above the audible range.
7. Method according to Claim 1, characterized in that the second manipulated variable (c), indicating the actual direction of rotation, is determined by sensors

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assigned to the motor (7).

8. Method according to Claim 1, characterized in that the information about the desired braking effect is derived via sensors from the motor (7) and/or from typical motor data.

9. Circuit for a method according to Claim 2, characterized in that the circuit is designed as a logic circuit (5), which has three inputs (a, b, c) for the pulse-width-modulated pulses (a), for the first manipulated variable (b) and for the second manipulated variable (c), and two outputs (d, e) for the reversal of polarity of the winding and for the motor drive (Figure 3).

10. Circuit according to Claim 9, characterized in that a terminal (a) carrying the pulse-width-modulated pulses is connected to the first inputs of an AND gate (3) and of an OR gate (4), a terminal (b) carrying the first manipulated variable is connected to the first inputs of a first EXOR gate (1) and of a second EXOR gate (2), a terminal (c) carrying the second manipulated variable is connected to the second input of the first EXOR gate (1), in that the output of the first EXOR gate (1) is connected to the second inputs of the AND gate (3) and of the OR gate (4) and the output of the AND gate (3) is connected to the second input of the second EXOR gate (2), and in that the output of the OR gate (4) supplies the pulses for driving the motor (7) and the output (d) of the second EXOR gate (2) supplies a switching voltage for reversing the polarity of the winding.

11. Method according to Claim 1, characterized in that pulses of constant amplitude do not need to be used for driving.

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Abstract

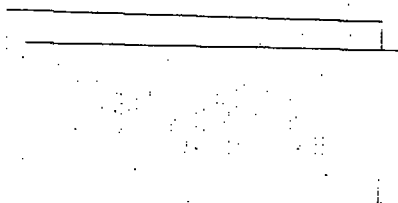
Method of controlling a motor

It is known to control motors in so-called chopper operation with a pulse-width modulated voltage of constant amplitude. For the purposes of braking or reversal of the direction of rotation, a motor winding has its polarity changed in each case. It has been shown that in many other applications, for example in the case of a capstan motor of a video recorder, the braking is carried out too rapidly. It is the object to provide a method using chopper operation which enables a defined braking effect for the motor.

An intermittent reversal of polarity of the winding is carried out the [sic] time intervals separated by pauses and whose duration depends on the respectively desired braking effect.

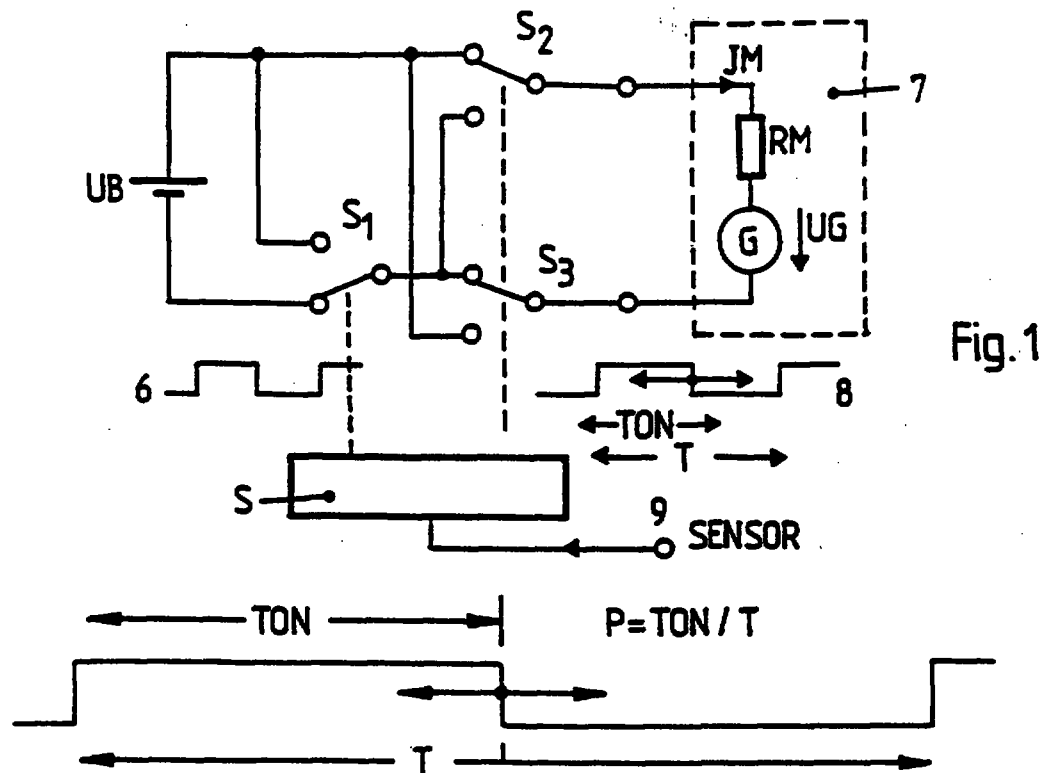
In particular for the capstan motor in a video recorder

Fig. 1



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A) $IM = -\frac{P \cdot UB}{RM} + \frac{UG}{RM}$

$IM = \frac{P \cdot UB}{RM} + \frac{UG}{RM}$

B) $P=0 : IM = \frac{UG}{RM}$

$IM = \frac{UG}{RM}$

C) $P = \frac{UG}{UB} : IM = 0$

$IM = 2 \cdot \frac{UG}{RM}$

D) $P = 2 \frac{UG}{UB} : IM = -\frac{UG}{RM}$

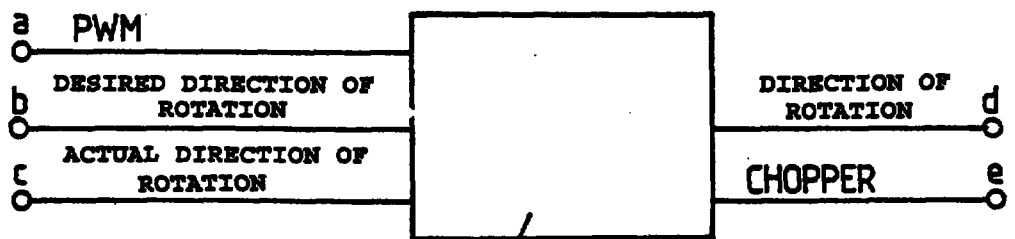
$IM = 3 \cdot \frac{UG}{RM}$

E) $P=1 : IM = -\frac{UB}{RM} + \frac{UG}{RM}$

$IM = \frac{UB}{RM} + \frac{UG}{RM}$

Fig. 2

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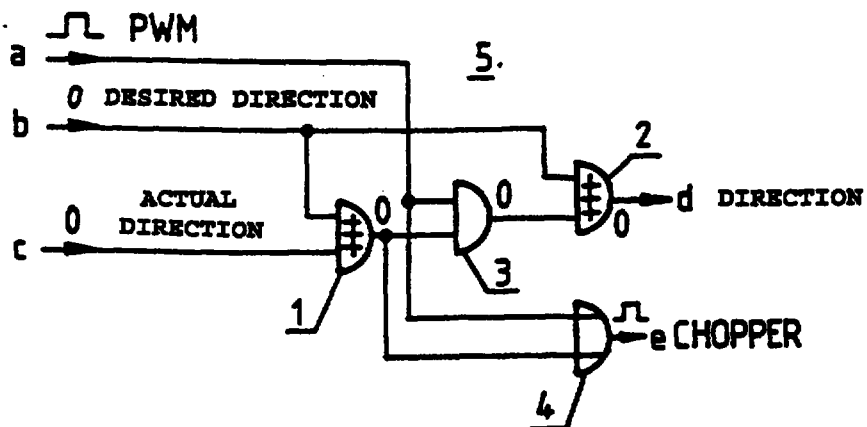


Fig. 4

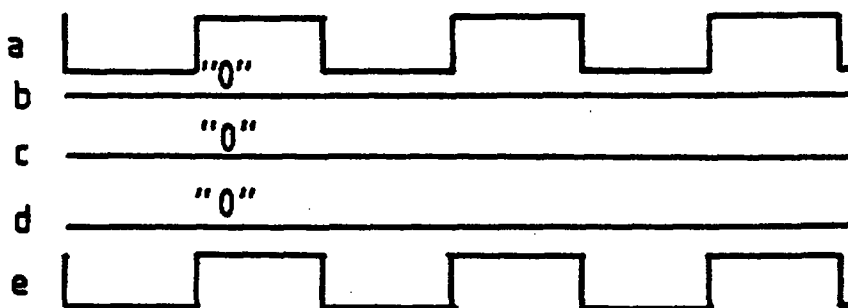


Fig. 5

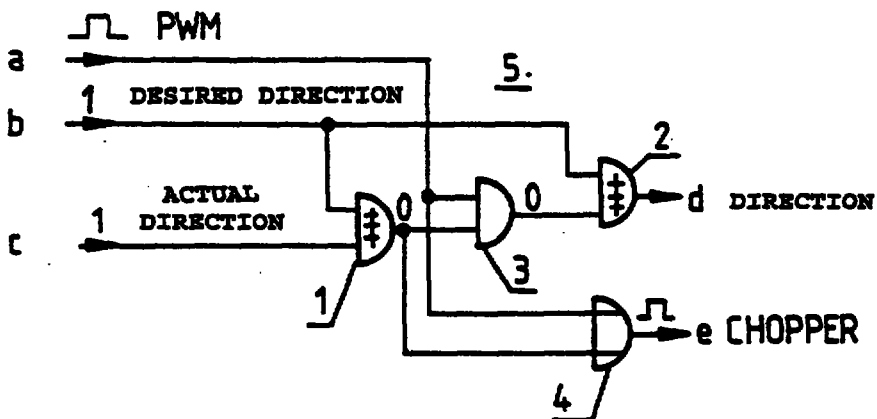


Fig. 6

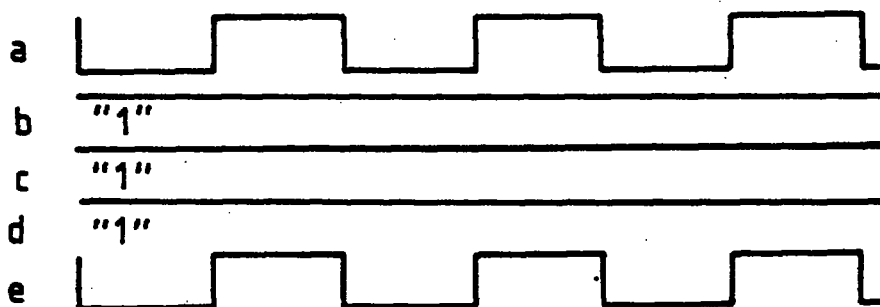


Fig. 7

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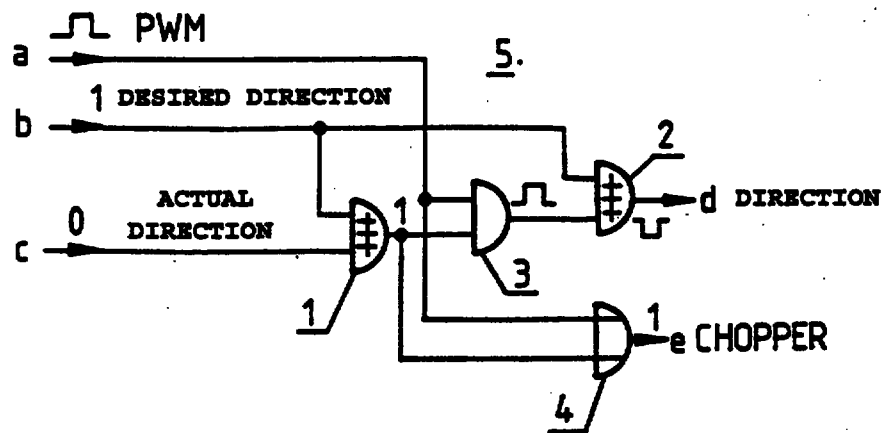


Fig.8

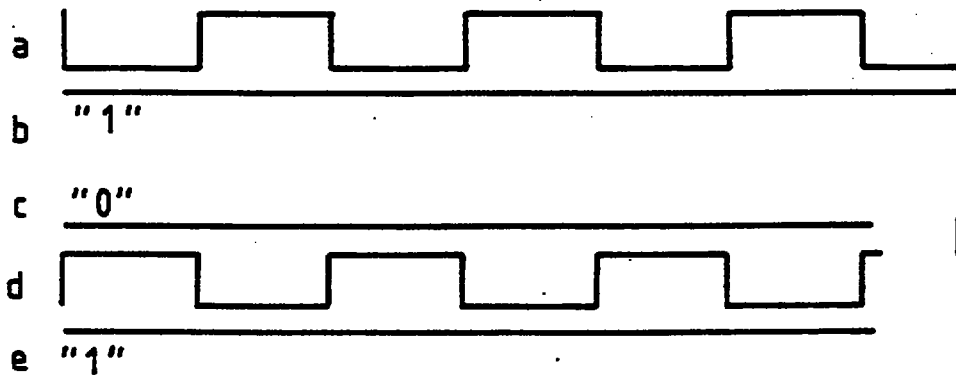


Fig.9

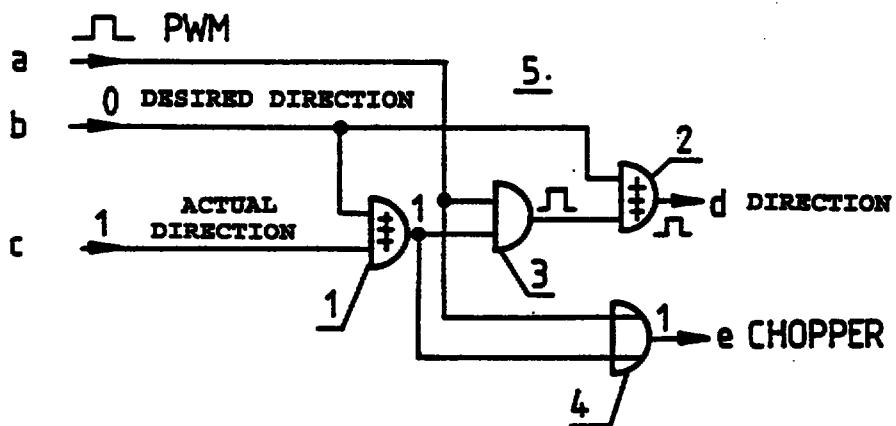


Fig.10

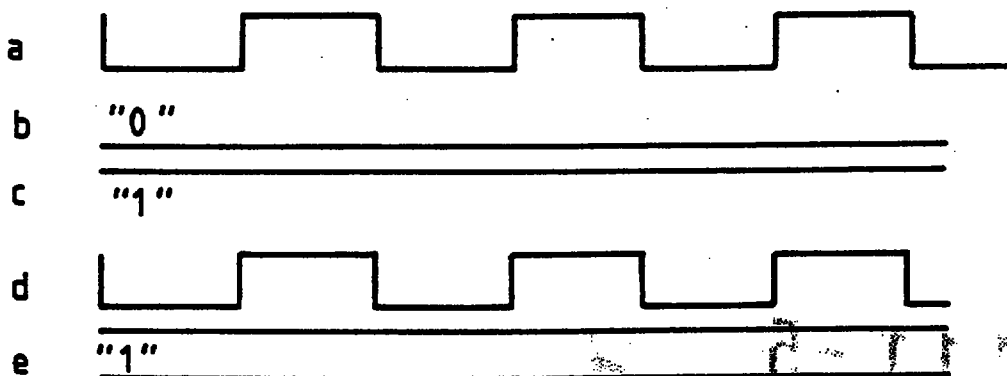
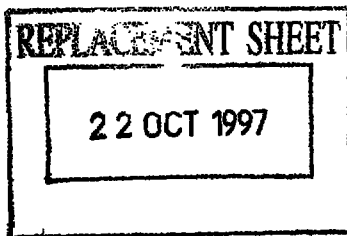


Fig.11



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REPLACEMENT SHEETS		SG
☒ Description	: paged ..1.. to paged ..7...	
☒ Claim(s)	: paged ..8.. to paged ..10..	
☒ Drawing(s)	: paged ..1/2.. to paged ..3/4..	
☐ Abstract	: paged to paged	
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Method for the control of a motor

The invention is based upon a method in accordance with the preamble of claim 1 or a device in accordance with the preamble of claim 9. Such a device is known from DE-A-4038199. It is known to feed motors, not with a direct voltage of variable magnitude, but rather, with a pulse width modulated voltage of constant amplitude, wherein the pulse width modulation (PWM) determines the prevailing torque or the rotational speed. This operation is also known as chopper mode. The frequency of the pulse width modulated pulses lies above the audible range on the one hand so as to avoid the motor control being audible and on the other hand so as to ensure that, despite the pulsed control, a practically direct current, the magnitude of which is determined by the PWM, flows in the winding of the motor due to the integrating effect.

For starting a braking process of the motor or for changing the direction of rotation, it is known to reverse the poles of the motor windings within the circuit on these occasions so that the motor is suddenly driven in the opposite direction of rotation. Initially, the motor then runs in its former direction of rotation, is braked during this time and then adopts the opposed direction of rotation. The following difficulty arises with this type of braking.

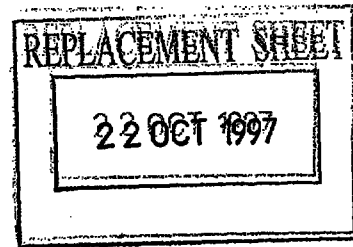
The ends of the motor windings are connected to the operating voltage or to earth via protective diodes. The diodes serve to protect the connected semiconductor components from destruction by voltage peaks in the motor windings. If now, a motor winding is reverse poled at the beginning of a braking process, a high current, which is produced by the generator voltage or EMF generated by the motor and the resistance of the motor winding, flows independently of the control action due to the effect of the said diodes. Thus current acts as a braking

current due to the rotation of the motor i.e. due to the relative movement between the motor windings and the permanent magnets. Since this current cannot fall below the rated value, the braking effect can, in many cases, be too great. If, for example, the motor is the capstan motor in a video recorder and the braking of the tape advancing mechanism occurs too rapidly, then loops of magnetic tape can build up due to the inertia of the feed spool which continues to run.

The object of the invention is to provide a method for the control of a motor using pulse width modulated control which makes possible a defined braking effect. This object is achieved by the invention defined in claim 1 and 9. Advantageous developments of the invention are specified in the appendant claims.

Thus, with the invention, a static reversal of the poles of the motor winding relative to the feed terminals for the starting of the braking process is not carried out but rather, there is an intermittent reversal of the poles. During a period, which is preferably equal to the period of the pulse width modulated voltage, the said reversal of the poles of the winding occurs for a certain time while this reversal of the poles is removed for the remaining time of the period. By selection of the pulse/pause ratio in this intermittent reversal of the poles of the winding, the braking effect can be altered within wide limits. An alteration of the frequency or amplitude of the actual pulse width modulated operating voltage for the motor is not thereby required.

Preferably, a first control variable indicating the derived direction of rotation and a second control variable indicating the actual direction of rotation are compared and a third control variable occurring upon deviation initiates the intermittent



reversal of the poles of the winding. The ratio of the duration of the said reversal of the poles to the total period of intermittent reversal of the poles is preferably variable between the values 0 and 1. The pulse width modulated pulses and the switching voltage for the intermittent reversal of the poles are preferably derived from the same pulse voltage. With coincidence between the derived and the actual direction of rotation, the motor is only fed by the pulse width modulated pulses in the sense of a constant direction of rotation and with non-coincidence between the derived and the actual direction of rotation, the motor is fed alternately in the sense of an opposed direction of rotation. The second control variable indicating the actual direction of rotation is preferably determined by sensors associated with the motor. The information regarding the desired braking effect is preferably derived via sensors of the motor and/or from data typical to the motor.

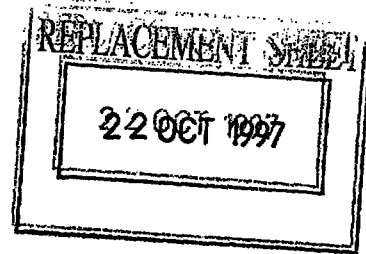
The invention will be explained in detail hereinafter with the help of the drawing. Therein

Fig.1 shows a basic wiring diagram for the method in accordance with the invention,

Fig.2 shows a diagram for the currents arising from the intermittent reversal of the poles with different pulse/pause ratios,

Fig.3 shows a basic block diagram of the method in accordance with the invention; and

Figs 4-11 show a logic circuit for various operational states.



In the description, the symbols used have the following meaning:

UB constant operating voltage for the feeding of the motor

UG EMF induced in the motor winding

IM current through the motor

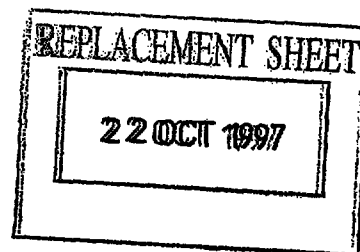
RM resistance of the motor winding

T period of the pulse width modulated voltage and the intermittent reversal of the poles

ton duration of the reversal of the poles during the period of the intermittent reversal of the poles

$$P = \text{ton}/T$$

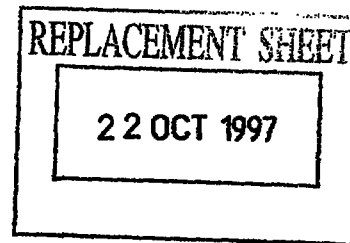
In Fig.1, the operating voltage UB is converted by the switch S1 into a pulse width modulated pulse voltage. S1 is actuated by the control circuit S by means of the pulse width modulated pulse voltage 6. The pulse width modulated pulse voltage thus arising arrives from the output of S1 via the change over switches S2, S3 to the motor 7 for which the generator G producing the induced voltage UG or EMF and the resistance RM of the motor winding are illustrated. For the starting of a braking process, the switches S2, S3 are placed in the other position by the control circuit S. This means, that the winding of the motor 7 is reverse poled relative to the feed voltage. This reversal of the poles does not always occur statically but can also be intermittent as is illustrated by the switching voltage 8. The duration ton of the reversal of the poles by the switches S2, S3 relative to the period T of the intermittent reversal of the poles determines the braking torque. The value of ton and thus the braking torque are determined by a control circuit S. This receives via the terminal 9 additional information from sensors regarding mechanical or electrical motor values.



By means of Fig.2 with the aid of equations, it is explained how a currently desired braking effect is achievable by alteration of the duty ratio $P = t_{on}/T$. The equation A indicates the motor current I_M , firstly for the time t_{on} and then for the succeeding pause $T-t_{on}$. The equation A is thus generally applicable. Equation B indicates the resulting current for $P = 0$, equation C for a special P , equation D for another P and equation E for the other limiting value $P = 1$. Since the current I_M is integrated over the total period T , the current value integrated over the times t_{on} and $T-t_{on}$ is in each case decisive for the braking effect. It is apparent that this value may be very small or even zero for certain values between $P = 0$ and $P = 1$. If for example, the negative expression in the equations $= U_G/R_M$, the integrated current value is practically zero. Consequently, by selection of P between 0 and 1 i.e. between absolutely no resulting reversal of the poles and continues reversal of the poles, the currently desired braking effect can be set.

Fig.3 depicts a simplified block diagram for the realisation of the method in accordance with the invention. A logic circuit 5 which has three inputs a, b, c is illustrated. The pulse width modulated pulse voltage, as is present on the output of S1 in Fig.1, is supplied to the input a. The first control variable indicating the derived direction of rotation is supplied to the input b and the second control variable indicating the actual direction of rotation is supplied to the input c. The circuit 5 has two outputs d and e. The output d controls the reversal of the poles of the winding by the switches S2, S3. The output e carries the actual pulse width modulated feed voltage as is present on the output of S1 in Fig.1.

In the Figures 4 - 11, the letters a - e indicate which voltages in accordance with Figs. 5,7,9,10 are present on the corresponding inputs a,b,c and outputs d,e in the Figs. 4,6,8,10.



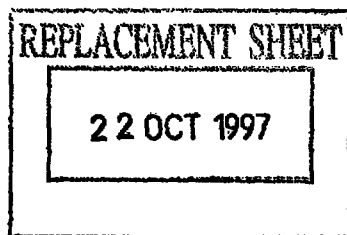
Figs. 4,5 show one possible practical realisation of the circuit 5 in accordance with Fig.3. The circuit 5 contains a first EXOR gate 1, a second EXOR gate 2, an AND gate 3 and an OR gate 4. Fig.4 applies for the case that the derived direction of rotation and the actual direction of rotation are the same i.e. both control variables at the inputs b,c have the value 0. The value 0 then appears at the output d so that, in the desired manner, the direction of rotation is not changed over. The actual pulse width modulated voltage for the feeding of the motor is present on the output e. This is the case where the motor runs in its derived direction of rotation and thus a reversal of the poles of a winding should not occur.

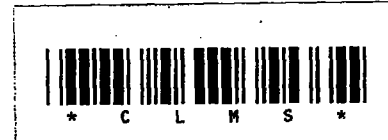
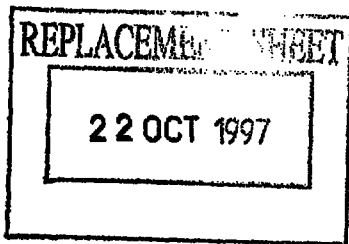
Figs. 6,7 show the same conditions for static operation with coincidence between derived direction and actual direction but for the other direction of rotation.

Figs. 8, 9 show the case that the control variable at the input b for the derived direction of rotation and the control variable at the input c for the actual direction of rotation deviate from each other. The output e, which carries the pulse width modulated voltage in Figs. 4-7, now remains at 1. Initially, this means, that the full operating voltage UB is continuously present at the output of S1 in Fig.1. The output d, which effects the reversal of the poles of the motor winding, now corresponds to the pulse width modulated voltage at the input a. This means, that the motor winding is now intermittently reverse poled in correspondence with the value P in accordance with Fig.2.

Figs. 10,11 apply correspondingly for the case that the derived direction of rotation and the actual direction of rotation have the respective other value in comparison with Figs. 8,9. Otherwise, the effect is similar to Figs. 8,9 with the

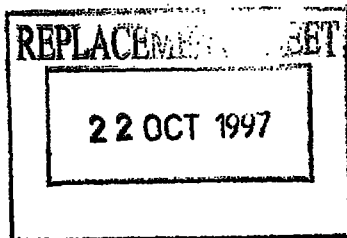
difference that now the pulse voltage at the output d, which causes the reversal of the poles of the motor, is rotated through 180° relative to Fig.9. It is apparent that the pulse voltage for the feeding of the motor on the one hand and the pulse voltage for the reversal of the poles of the motor winding for the braking process are derived from the same input voltage at the terminal a. The actual energy feed of the motor comes continually from the output e of the circuit 5 while the output d controls the reversal of the poles of the winding in correspondence with the switches S2, S3 in Fig.1.





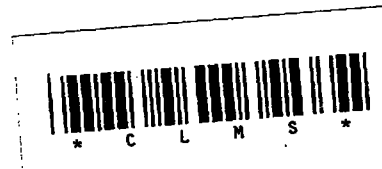
CLAIMS

1. A method for the control of a motor in which pulse width modulated pulses (a) are supplied to a motor winding and the winding is reverse poled for starting a braking process, characterised in that, an intermittent reversal of the poles of the winding is effected for time periods (ton) which are separated by pauses (T-ton) and the duration of which is dependent upon the currently desired braking effect.
2. A method in accordance with Claim 1, characterised in that, a first control variable (b) indicating the desired direction of rotation and a second control variable (c) indicating the actual direction of rotation are compared and a third control variable (d) occurring upon deviation initiates the intermittent reversal of the poles of the winding.
3. A method in accordance with Claim 1, characterised in that, the ratio (P) of the duration (ton) of the reversal of the poles to the period (T) comprising the reversal of the poles and the pause is variable between the values 0 and 1.
4. A method in accordance with Claim 1, characterised in that, the pulse width modulated pulses (e) and a switching voltage (d) for the intermittent reversal of the poles are derived from the same pulse voltage (a).
5. A method in accordance with Claim 1, characterised in that, with coincidence between the desired and the actual direction of rotation, the motor (7) is only fed by the pulse width modulated pulses (e) in the sense of a constant direction of rotation and for non-coincidence between the desired and the actual



direction of rotation, the motor (7) is fed alternately in the sense of an opposed direction of rotation.

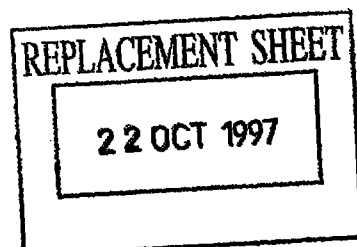
6. A method in accordance with Claim 1, characterised in that, the frequency of the pulse width modulated pulses (a,e) lies above the audible range.
7. A method in accordance with Claim 1, characterised in that, the second control variable (c) indicating the actual direction of rotation is determined by sensors associated with the motor (7).
8. A method in accordance with Claim 1, characterised in that, the information regarding the desired braking effect is derived via sensors of the motor (7) and/or from data typical to the motor.
9. A circuit for a method in accordance with Claim 2, for the control of a motor, with means for supplying pulse width modulated pulses (a) to a motor winding,
with means for reversal of the poles of the winding for starting a braking process, characterised in that, the reversal of the poles occurs intermittently for time periods (ton) which are separated by pauses (T-ton) and the duration of which is dependent upon the currently desired braking effect,
means being provided for the comparison of a first control variable (b) indicating the desired direction of rotation and a second control variable (c) indicating the actual direction of rotation,
a third control variable (d) occurring upon deviation initiating the intermittent reversal of the poles of the winding, the circuit being formed as a logic circuit (5) which has three inputs (a,b,c) for the pulse width modulated pulses (a), for the first control variable (b) and for the second control variable (c) and two

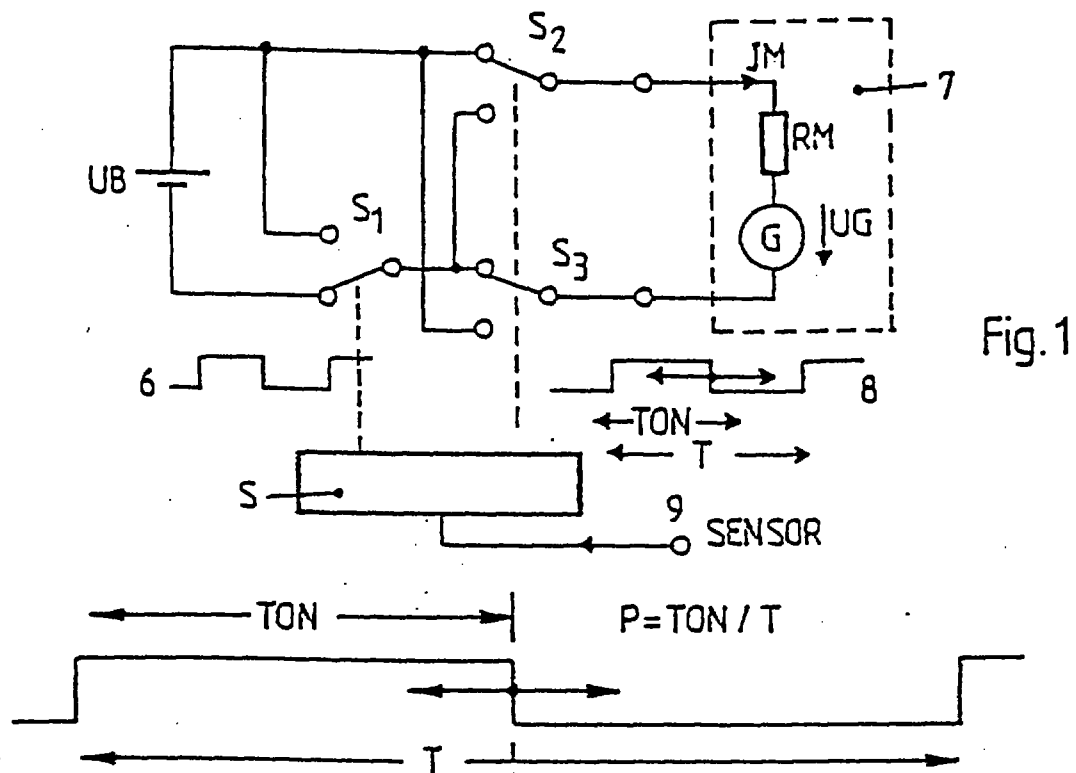


outputs (d,e) for the reversal of the poles of the winding and of the motor drive (Fig.3).

10. A circuit in accordance with Claim 9, characterised in that, a terminal (a) carrying the pulse width modulated pulses is connected to the first inputs of an AND gate (3) and to an OR gate (4), a terminal (b) carrying the first control variable is connected to the first inputs of a first EXOR gate (1) and of a second EXOR gate (2), a terminal (c) carrying the second control variable is connected to the second input of the first EXOR gate (1), that the output of the first EXOR gate (1) is connected to the second inputs of the AND gate (3) and of the OR gate (4) and the output of the AND gate (3) is connected to the second input of the second EXOR gate (2) and that the output of the OR gate (4) supplies the pulses for the deriving of the motor (7) and the output (d) of the second EXOR gate (2) supplies a switching voltage for the reversal of the poles of the winding.

11. A method in accordance with Claim 1, characterised in that, pulses of constant amplitude need not be used for the control.





A) $IM = -\frac{P \cdot UB}{RM} + \frac{UG}{RM}$

$IM = \frac{P \cdot UB}{RM} + \frac{UG}{RM}$

B) $P=0 : IM = \frac{UG}{RM}$

$IM = \frac{UG}{RM}$

C) $P = \frac{UG}{UB} : IM = 0$

$IM = 2 \cdot \frac{UG}{RM}$

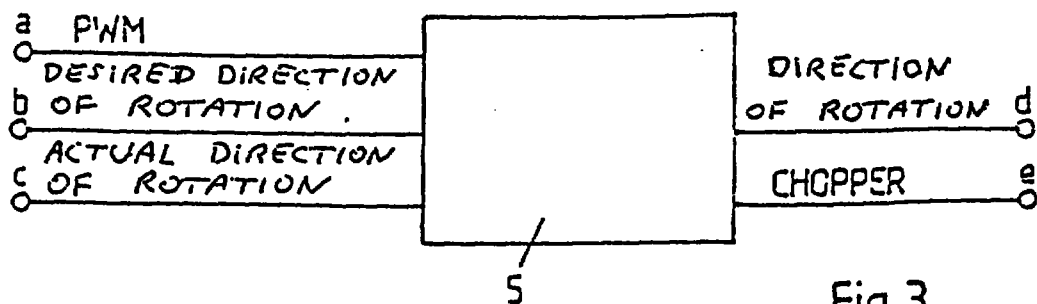
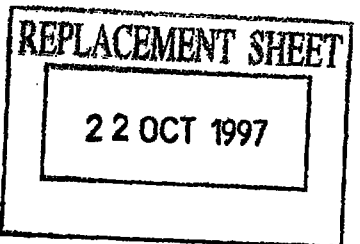
D) $P = 2 \frac{UG}{UB} : IM = -\frac{UG}{RM}$

$IM = 3 \cdot \frac{UG}{RM}$

E) $P=1 : IM = -\frac{UB}{RM} + \frac{UG}{RM}$

$IM = \frac{UB}{RM} + \frac{UG}{RM}$

Fig.2



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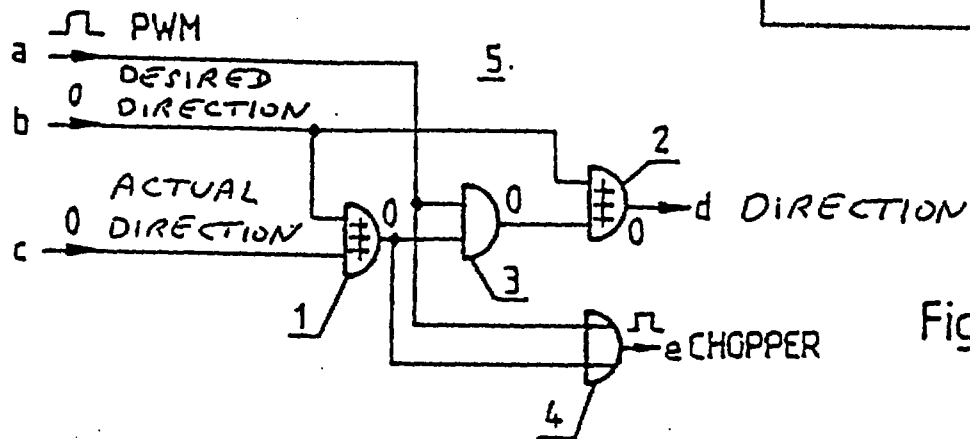


Fig. 4

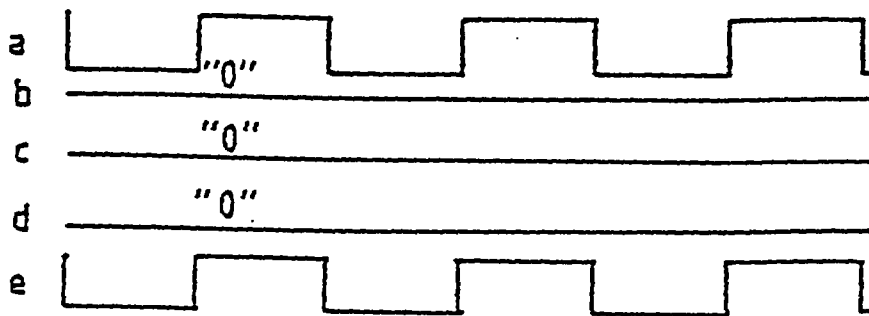


Fig. 5

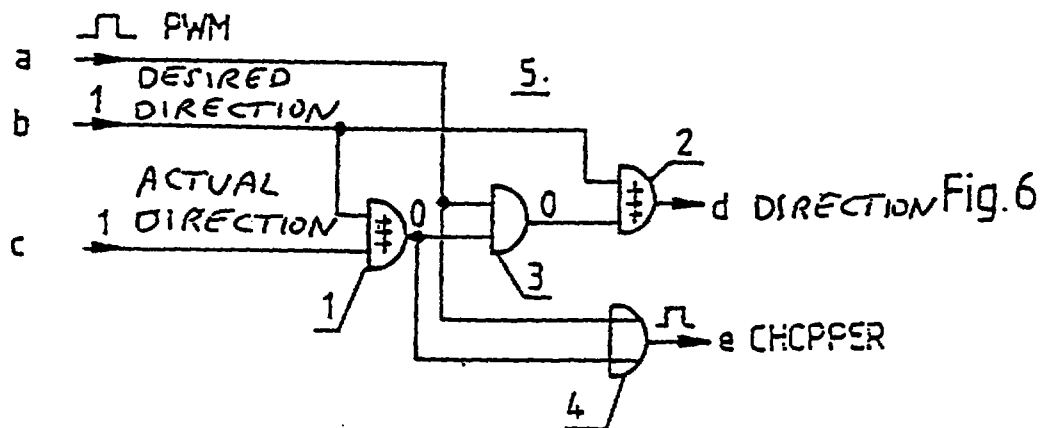


Fig. 6

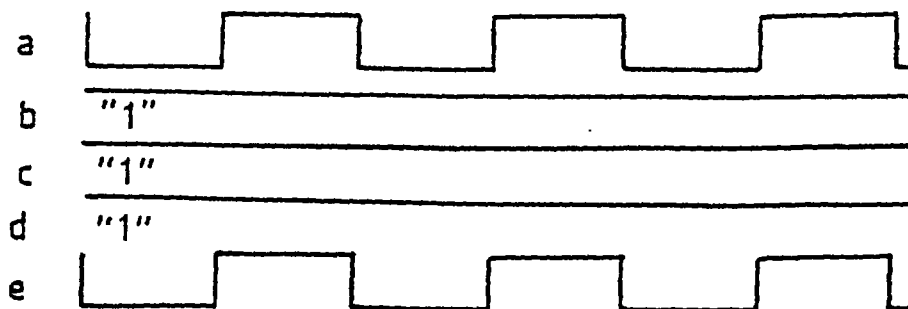


Fig. 7

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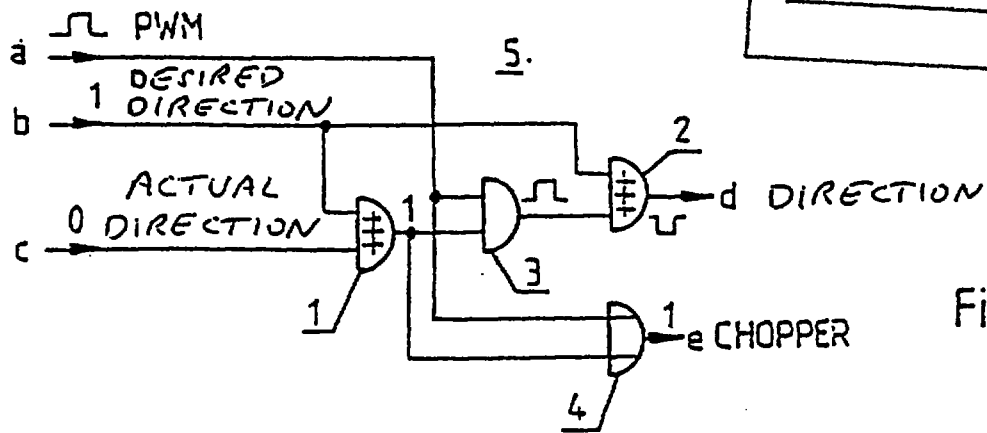


Fig.8

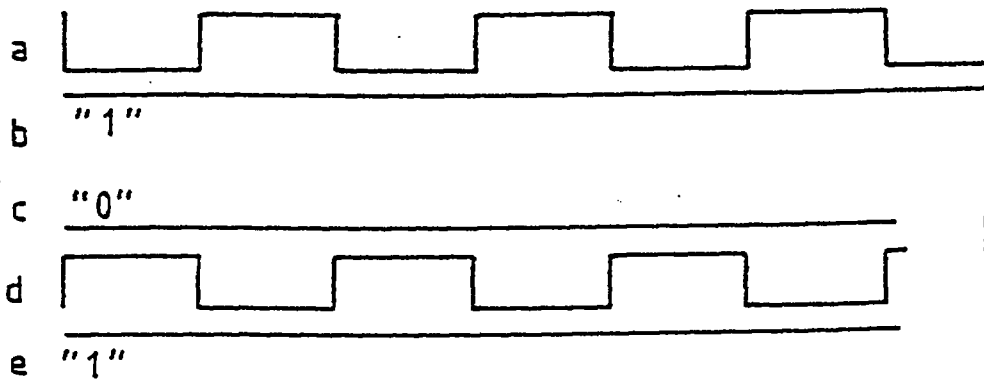


Fig.9

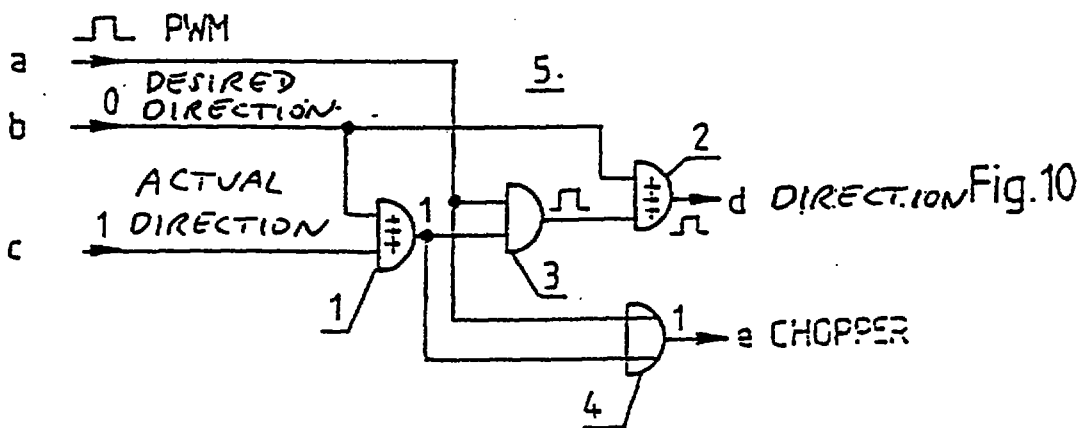


Fig.10

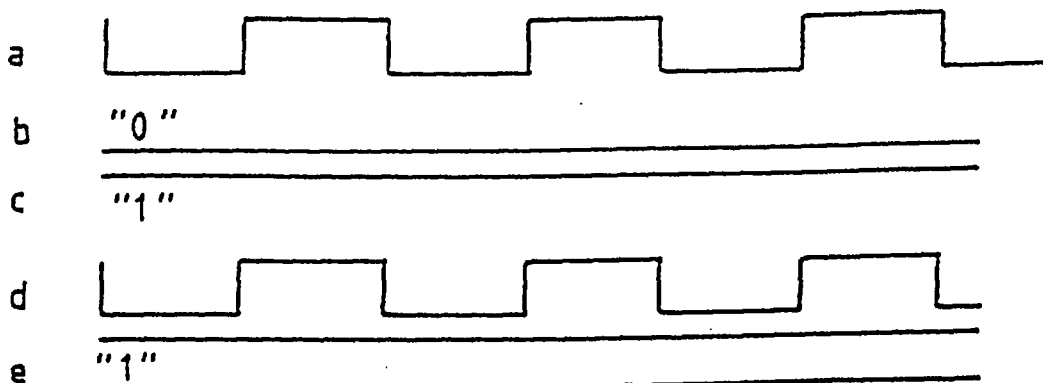


Fig.11