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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
5 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
10 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:
15 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
20 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.

25 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
30 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
35 $P = \text{ton}/T$

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 ton 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 ton 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 $P = \text{ton}/T$. Equation A shows the motor current i_M , to be specific on the one hand for the time ton and on the other hand for the subsequent pause T-ton. 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 ton and T-ton 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 (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



assigned to the motor (7).

5 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
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
15 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
20 (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)
25 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.

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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