

Known electronically commuted DC motors, e.g. for use in magnetic tape recorders, are equipped with a plurality of position sensors, e.g. Hall elements, which are each associated with a coil lead. The sensors are aligned in a permanent three-dimensional arrangement relative to the position of the coils. Signals, whereby the current angular position of the rotor is recognised, are generated in the sensors by rotation e.g. of a rotor carrying multipolar permanent magnets. These signals trigger each particular coil commutation. Such motors also require a frequency generator supplying information, i.e. signals proportional to the motor speed. Both types of information are required in order to control the motor by means of electronic circuits.

Other known motors are controlled by means of a light barrier in conjunction with a plurality of line marks distributed over the rotor, the line marks being specifically allocated to the commutable coils located in the stator (e.g. US-A-4584505).

The problem underlying the invention is to produce the commutation sequence of such a motor with only one stationary sensor in any location. It is solved by the invention characterised in claim 1. Further embodiments of the invention are described in the subclaims.

In a motor for use e.g. in a video recorder, two pieces of information are in principle discharged during one revolution of the motor by the pulse delivered by a sensor, e.g. a light barrier, this information initiating commutation of the motor. The first information, viz the pulse start, serves to recognise the angular position of the rotor, while the second information, viz the pulse length, generated e.g. by the aperture of the light barrier, is a measure of the rotational speed.

To initiate commutation for a first coil lead from these pieces of information, a signal shape is derived from the current rotational speed and is extended by a second signal shape, generated in a circuit, at the end of which commutation is

initiated. The second signal shape is proportional to the first, i.e. linked to the first signal shape by a certain factor K .

When a motor is started, the actual duration of the first signal is long and that of the second signal is also proportionately long, since the angular speed of the rotor is correspondingly low, and hence the time for applying the correct commutation is likewise correspondingly long. When the motor has reached its required speed the angular speed is relatively high. The actual duration of the first signal is therefore short and that of the second signal, which is proportional to that of the first, is similarly short, so that the correct commutation point is reached more rapidly, dependent on the higher angular speed.

The link between the actual signal duration and the second, generated signal duration is provided by a proportionality factor K , which is determined empirically for a motor according to the relative geometric arrangement of the sensor and coils. This factor may e.g. be stipulated by setting a minimum current input for nominal speed for a motor. The proportionality factor can also be adjusted so that a maximum torque is delivered by the motor at nominal speed.

The factor may be varied appropriately for a motor control, i.e. for different operative states such as acceleration, braking and change of rotational direction, thus producing different commutation initiation points for these states.

The first initiation of a commutation is determined in each case by the arrangement previously described. Commutation of the succeeding coil leads may be effected e.g. by counters or, according to the invention, by cascading the principle previously described. From the end of the second signal duration, cascading of further signal durations, generated proportionately to the actual signal duration, causes commutation to be initiated for the following coil leads at the end of each of these signal durations. Means for determining the commutation point, cascaded in this way, may be controlled by a microprocessor.

An example of the invention will now be described by reference to the accompanying drawings, in which:

Fig. 1 is a block diagram of a circuit for carrying out the method of controlling the instant of commutation,

Fig. 2 shows voltage shapes in Fig. 1 at various speeds,

Fig. 3 is similar to Fig. 2 and shows voltage shapes in Fig. 1 at the same speed and with different commutation initiation points, and

Fig. 4 is a block diagram showing the layout for commuting a plurality of coil leads by cascading the Fig. 1 circuit.

Fig. 1 is a block circuit diagram showing a rotary position transducer 1 fixed on a motor spindle and generating a signal S1 in a sensor 2. The signal S1 has an actual duration T1, dependent on the rotational speed, which is predetermined by the aperture of the transducer 1, e.g. in the case of a light barrier. T1 is long at a low speed and short at a high one. A permanent angle is predetermined by the relative geometrical arrangement of the transducer 1 and the motor coils to be commuted (not shown). This angle can be selected freely and may vary from one motor to another. Initiation of commutation, i.e. the moment when there is a switchover from one coil lead to the next, is thus dependent on the angle subtended by the start of signal S1 and the desired optimum commutation point t2.

For a better understanding of the circuit it will be assumed that the actual duration T1 of signal S1 at nominal speed is shorter than the time from the start of signal S1 to the instant of commutation t2. That is to say, the instant of commutation t2 is after the actual signal duration T1 has elapsed and, for even commutation, is proportionately dependent on the actual signal duration T1 in accordance with the formula:

$$t2 = T1 + K \cdot T1$$

The proportionality factor K has to be determined for each motor according to requirements for the desired instant of commutation.

Thus this factor may be set for minimum current input at nominal speed or for optimum torque at nominal speed.

The signal S1 of actual duration T1 is passed by sensor 2 to the amplifier 3. The output A of amplifier 3 controls a current source 4 and, by way of an inverter 6, a current sink 5. The outputs of current source 4 and current sink 5 are brought together at a connecting point B, which is connected to a capacitor 8. The capacitor 8 is charged from the current source 4 for the duration of T1. At the end of T1 charging stops and discharging is initiated for the capacitor 8 through the current sink 5. The discharging process, i.e. the current in the sink 5, can be adjusted through a control input E. The starting point of the charging of capacitor 8 is recognised by a zero voltage comparator 9 connected in parallel with the capacitor 8; the output C of the comparator is switched to "high" when charging starts. When the capacitor 8 has been discharged to zero volt by the current sink 5, the output C of comparator 9 changes to "low". The comparator 9 is connected to a pulse-shaping circuit 10, which releases a pulse D when the zero volt mark is reached. The pulse D is used to initiate commutation of the first coil lead of the motor by triggering a circuit (not shown). It is also used to switch off the current sink 5, so that capacitor 8 is not discharged below the zero volt mark. This is done through the line G, which connects the output of the pulse-shaping circuit 10 to the current sink 5.

In its active state the current source 4, provided to charge the capacitor, supplies a constant current which is predetermined by the dimensions. In contrast, the current sink 5 used for discharge can be varied in its current intensity through its control connection E. There must be a linear relationship between the current of the sink 5 and a DC control voltage supplied at the control connection E through switch 23. The DC control voltage is tapped from the operating voltage $+U_B$ by means of a potentiometer 7, the strength of the voltage tapped being determined by the relative geometric arrangement of the sensor 2 and the motor coils to be commuted, and by the charging current

from current source 4. As already mentioned, this voltage may be set e.g. to minimum current at nominal speed or to maximum torque.

If the input E of current sink 5 is connected to the output of microprocessor 11 by switch 23, various operative states can be set for the motor by means of the microprocessor, which is provided with a D/A converter. Thus it is possible to input clockwise rotation, anticlockwise rotation, acceleration and braking through the microprocessor 11, by changing the instant of commutation.

The subsequent coil leads of the motor may be commuted by counting circuits, from the point of initiation of the described commutation of the first coil lead, or by cascading as illustrated in Fig. 4. In the Fig. 1 circuit described, the instant of commutation is produced by converting the signal duration T1 and the signal duration T2, generated proportionately to the first signal duration T1, to processes of charging and discharging a capacitor 8. However it is also possible to convert these signal durations to frequency sequences and to determine the instant of commutation by means of counting circuits.

Fig. 2 shows voltage shapes in Fig. 1 at various speeds of a motor. Three different speeds are shown, such as may occur e.g. with motor control by a frequency generator. The characterising letters A, B, C and D correspond to the points indicated in the circuit diagram. A shows the voltage shape at the output of the pre-amplifier 3. This shape corresponds to the signal S1 with a duration T1. B shows the processes of charging and discharging the capacitor 8. The capacitor is charged with constant current during the time T1, while discharge through the current sink 5 takes place immediately after the charging process. The amount of discharge in the time T2 is predetermined by the DC control voltage, which is set for an optimum commutation process by means of potentiometer 7. It will be seen that the charging to discharging ratio is always the same (here 2:3). C shows the signal shape at the output of the zero voltage comparator 9. When charging is started the zero voltage comparator switches to

"high", and when discharge is over, i.e. at the zero voltage mark, it switches over to "low". D shows the release of the trigger pulse at the output of the pulse-shaping circuit 10; it is released at the end of each discharging process, to initiate commutation and switch off the current sink 5.

Fig. 3, which is similar to Fig. 2, shows voltage shapes in Fig. 1 at the same motor speed. Commutation, i.e. the release of pulse D, is in each case varied by different discharging of the capacitor 8, whereby different operating conditions such as acceleration, braking or a change of rotational direction can be set. The different discharging of capacitor 8 is brought about e.g. by microprocessor 11, which is connected to the input E by switch 23.

Fig. 4 is a block diagram of a circuit for commuting a plurality of coil leads by cascading the Fig. 1 circuit. The blocks 12, 15 and 18 contain blocks 4, 5, 6, 8 and 9 illustrated in Fig. 1.

Sensor 2, acting through amplifier 3, supplies the actual signal duration T1 to the input of block 12 and simultaneously to the input of an inverter 14. The outputs of block 12 and inverter 14 are passed to a combinational circuit 13, from which the triggering signal D1 for a first coil lead to be commuted is transmitted via pulse shaper 10.

The output signal F1 from combinational circuit 13, which is switched to "high" at the end of T1, reaches the input of the further block 15 and inverter 17. Their outputs are again passed to a further combinational circuit 16, whereby the triggering pulse D2 for commutation of a second coil lead is released in conjunction with pulse shaping circuit 19. The output signal F2 from combinational circuit 16, which is switched to "high" when the zero volt mark of the capacitor in block 15 is reached, is now passed to a further block 18 and a further inverter 20 for commutation of a third coil lead by pulse D3 by means of combinational circuit 21 and pulse-shaping circuit 22.

Other arrangements of this type allow adaptation to various numbers of motor leads (commutation for 3 leads has been described here). The various operating points for blocks 12, 15 and 18, i.e. the control voltages at block inputs E12, E15, E18, must be located so as to ensure gap-free alignment of commutation pulses for the various coil leads.

Fig. 5 shows the voltage shapes which occur and what they are associated with, beside the block circuit diagram.



CLAIMS

1. A method of controlling commutation for coils of a DC motor with a stationary sensor, wherein a signal (S1) with an actual signal time (T1) is generated during a revolution of the rotor, characterised in that the actual signal time (T1) is extended by a second signal time ($K \cdot T1 = T2$) produced proportionally to the actual signal time (T1), and that application for commutation of a first coil lead takes place at the end (t2) of the second signal time (T2).
2. The method of claim 1, characterised in that the proportionality factor (K) for optimum commutation use is adjustable.
3. The method of claim 1, characterised in that the proportionality factor (K) can be changed while the motor is running, for various operative states such as acceleration, braking and reversing the rotation.
4. The method of claim 3, characterised in that the proportionality factor (K) can be controlled by a microprocessor.
5. The method of claim 1, characterised in that commutation of the second and subsequent coil leads from the end (t2) of the second signal time (T2) is applied by cascading further signal times (T3...TN) produced proportionally to the actual signal time (T1).
6. The method of claim 5, characterised in that the further signal times (T3...TN) can be controlled by a microprocessor.