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**Motor controller for electronically commutated DC motors in  
order to compensate for torque drops**

The invention relates to a motor controller having  
5 electronic commutation which is connected to the windings  
of a motor, a predetermined additional current being  
connected to that coil of the motor which is active at that  
moment, from the commutation instant, in order to prevent  
torque drops.

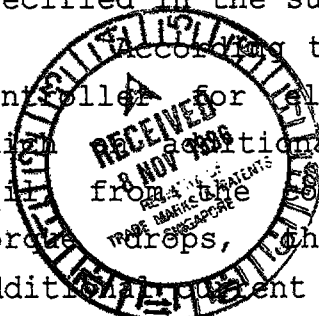
10 US-4,511,827 discloses a controller which drives an  
electronically commutated motor such that torque  
fluctuations are suppressed. This device in this case  
comprises a sensor for determining the rotor position, in  
other words the commutation instant, and a controller which  
15 processes this signal so that the corresponding coil is  
supplied, from the commutation instant, with additional  
current in order to prevent a torque drop.

However, it has been found in the case of the known  
solution that the supply of a predetermined current to the  
20 coil compensates for the torque drops only within a  
specific motor current range. However, for example, in a  
video recorder, the known method does not provide  
satisfactory results since, in an operating mode (for  
example play or long-play), the currents may be very  
25 different because of different mechanical loads, for  
example in the case of different temperatures or cassettes.

The invention is thus based on the object of  
providing a motor controller in which torque drops are  
avoided even in the event of different motor loads.

30 The object is achieved by the features of  
Claim 1. Preferred refinements of the invention are  
specified in the subclaims.

According to the invention, in the case of a motor  
controller for electronically commutated DC motors, in  
35 which an additional current is connected to the active  
coil from the commutation instant, in order to prevent  
torque drops, the duration and/or amplitude of the  
additional current pulse are/is determined as a function of  
the motor load. In other words, the duration and/or



amplitude of the additional current pulse are/is variable and are/is derived from the load on the motor, the additional current pulse being longer (greater) the higher the motor load, as is self-evident.

5           This advantageously results in torque drops being compensated for automatically and optimally, irrespective of the production scatter between motors, the temperature ranges and ageing.

10           The motor controller according to the invention normally controls the motor by means of so-called pulse-width modulation (CPWM or PWM) of the control pulses. The PWM signal of the motor controller is held at "1" for the duration of the additional current. The commutation instant, from which the additional current is applied, can  
15 be determined by a sensor.

          The motor load is determined from the motor current drawn, it being possible to determine the motor current, for example, by means of a measurement resistor which is connected in the motor circuit or from the ratio of the  
20 pulse duration to the pulse pause of the PWM signal.

          Furthermore, the controller according to the invention may have an integrator which produces a control signal (S) from the duty ratio of the CPWM signal. The start of the integration of the CPWM control signals is  
25 likewise brought about by the occurrence of the commutation signal.

          The controller advantageously has a flipflop whose Q output is connected to the CPWM control signals via an "OR" gate, so that the Q output is switched to logic "1" on  
30 the occurrence of the commutation signal, the Q output of the flipflop being reset again when the control signal corresponds with a reference voltage. The comparison between the reference voltage and the control signal is preferably carried out by means of a differential  
35 amplifier. This also brings about the end of the integration of the CPWM signals.

          A preferred embodiment of the invention will be explained in the following text with reference to the figures, in which:



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Fig. 1 shows a circuit diagram of the compensation section, according to the invention, of the motor controller,

5 Figs. 2a and 2b show timing diagrams of the input and output signals required for control purposes, and

Figures 3a and 3b show the current waveform in an electronically commutated motor, respectively without and with compensation.

Fig. 1 shows the logic circuit for compensating for  
10 torque drops in digitally driven, electronically commutated motors. A digital motor control signal CPWM, in which the motor load can be derived from the duty ratio, is passed to the input of the compensation circuit 1. A control signal S is derived from this signal CPWM by means of an integrator  
15 2. The integrator 2 preferably comprises three serial resistors  $R_1$ ,  $R_2$  and  $R_3$ , as well as two capacitors  $C_1$  and  $C_2$ ,  $C_1$  being arranged electrically between earth (reference-earth potential) and the junction of  $R_1$  and  $R_2$ , and  $C_2$  being arranged electrically between earth and the junction of  $R_2$   
20 and  $R_3$ , and the control signal S being formed on  $C_2$ . The control signal CPWM for controlling the motor, which is not illustrated, is furthermore passed to an input of an OR gate 3, so that a PWM control signal appears at the output of the OR gate 3 and is supplied to PWM power stages, which  
25 are likewise not illustrated, in order to provide the motor current in the individual motor coils or windings.

The control signal S which is produced by the integrator 2 is supplied to the inverting input of a differential amplifier which is designed as a comparator 4  
30 and to whose non-inverting input a reference voltage  $U_{REF}$  is applied, which is defined via a voltage divider composed of resistors  $R_4$ ,  $R_5$ . The output of the comparator 4 is passed to the reset input of a flipflop 5, which is formed by a D flipflop. The D input of the flipflop 5 is at positive  
35 potential which can be derived, for example, from an operating voltage  $U_b$ . The occurrence of the commutation signal I for the motor drive activates the flipflop 5 via the clock input, so that a logic "1" appears at the Q output. The Q output of the flipflop 5 is passed to the

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other input of the OR gate 3. As a result of the CPWM signal being linked to the Q output by means of this OR circuit, the PWM signal for the power stages is in consequence held at logic "1" or at the "High" level, so that an additional current is supplied to the motor windings. The Q output of the flipflop 5 remains at logic "1" until logic "1" appears at the output of the comparator 4, so that the flipflop is reset via the reset input R of the flipflop 5 and, in consequence, a logic "0" appears at the Q output or the Q output is held at the "low" level. An npn transistor T is connected between the inverting input of the comparator 4 (control signal S) and the Q output of the flipflop 5, such that the base is connected to the Q output via a resistor  $R_6$ . The emitter of the transistor T, which is at the positive potential of the operating voltage  $U_b$ , is connected to the base via a resistor  $R_7$ , while the collector of transistor T is connected to the inverting input of the comparator 4. When the Q output of the flipflop 5 switches up to logic "1", the transistor T is switched off, while a logic "0" at the Q output of the flipflop 5 opens the transistor T, or switches it on.

The transistor T thus acts as an electronic switch by means of which the capacitor  $C_2$  on which the control signal S is formed can be charged to the positive potential of the operating voltage  $U_b$ , depending on the logic signal state at the Q output of the flipflop 5, or, when the Q output is switched to logic "0" or the "low" level, can be discharged to the potential which results on the capacitor  $C_1$  as a result of the continuous integration of the CPWM signals which are continuously supplied via the resistor  $R_1$ . The discharge time constant of the capacitor  $C_2$  is in this case essentially determined by the parallel circuit formed by the resistor  $R_3$  and the resistor  $R_2$ , the latter of which forms a series circuit with the capacitor  $C_1$  for discharging. The charging time constant of the capacitor  $C_2$  is determined by the resistance of the switched-on emitter-collector path through the transistor T.

Figures 2a and 2b show the waveform of the various control signals with respect to time, Fig. 2a illustrating

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the case when the motor load is low, and Fig. 2b illustrating the case when the motor load is high. The upper clock waveform in Fig. 2a shows the motor control signal CPWM, the duty ratio being relatively low. When the  
5 commutation signal I occurs, the Q output of the flipflop 5 is switched to the "High" level, so that the transistor T is switched off and defines the start of production of the control signal S. This means that the voltage on the capacitor C<sub>2</sub>, which corresponds to the control signal S, in  
10 consequence falls until the flipflop 5 is reset via the R input. This results in the lower clock waveform at the output of the OR gate 3, that is to say the output of the OR gate 3 is logic "1" for the duration of the current control signal S, which means a positive potential with  
15 respect to the reference-earth potential in the present case, while logic "0" is, for example, the reference-earth potential.

Fig. 2b shows the same situation as Fig. 2a, but with the motor control signal CPWM having a higher duty ratio. As a result of the higher duty ratio of the motor  
20 control signal CPWM, the capacitor C<sub>1</sub> is charged to a higher voltage in comparison with the situation according to Fig. 2a. The consequence of this is that the capacitor C<sub>2</sub> is discharged more slowly and the waveform of the current  
25 control signal S also lasts for a longer time, so that the time period for which the output of the OR gate 3 remains at logic "1" is significantly longer.

Fig. 3a shows the current waveform in one of the motor windings without the compensation according to the  
30 invention for torque drops. The upper part illustrates the instants of commutation. The lower part shows the current waveform as a function of time. It can clearly be seen that drops occur in the current waveform and thus also in the torque waveform of a motor at the commutation instants.

35 In contrast to this, Fig. 3b shows the current waveform in one of the motor windings where current and/or voltage compensation are/is used in order to avoid torque drops. The current waveform, and thus the torque waveform



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of the motor, is approximately constant at the commutation instants.

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## Patent Claims



1. Motor controller for electronically commutated DC  
5 motors, in which an additional current and/or voltage is  
connected to the active motor winding from the commutation  
instant in order to prevent torque drops, **characterized in**  
**that** the duration and/or amplitude of the additional  
current and/or voltage pulse is derived from the motor  
10 load.
2. Motor controller according to Claim 1,  
**characterized in that** the motor is driven by pulse-width  
modulation (PWM).
3. Motor controller according to Claim 2,  
15 **characterized in that** the PWM signal is held at logic "1"  
for the duration of the additional current and/or voltage.
4. Motor controller according to one of the preceding  
claims, **characterized in that** the commutation instant is  
determined by a sensor.
- 20 5. Motor controller according to one of the preceding  
claims, **characterized in that** the motor load is determined  
from the motor current drawn.
6. Motor controller according to Claim 5,  
**characterized in that** the motor current is determined by a  
25 measurement resistor in the motor circuit.
7. Motor controller according to Claim 4,  
**characterized in that** the motor current is determined from  
the ratio of the pulse duration to the pulse pause in the  
PWM signal and/or from the motor rotation speed.
- 30 8. Motor controller according to Claim 7,  
**characterized in that** the controller has an integrator (2)  
which produces a control signal (S) from the duty ratio of  
the PWM signal.
9. Motor controller according to Claim 8,  
35 **characterized in that** the controller furthermore has a  
flipflop (5) whose Q output together with the PWM control  
signal form the inputs of an OR gate, so that the Q output  
is switched to logic "1" on the arrival of the commutation  
signal (I), and the Q output is reset again when the

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control signal (S) corresponds with a reference voltage ( $U_{REF}$ ).

10. Motor controller according to Claim 9, characterized in that the comparison between the reference  
5 voltage ( $U_{REF}$ ) and the control signal (S) is carried out by means of a differential amplifier (4).



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**Abstract**

In the case of a motor controller for electronically commutated DC motors, an additional current and/or an additional voltage is passed at the commutation instant to that winding of the motor which is active at that time, in order to prevent torque drops. In order to compensate for torque drops at different motor loads, the duration and/or amplitude of the additional current and/or of the additional voltage are/is determined from the actual motor load.

[Fig.1]

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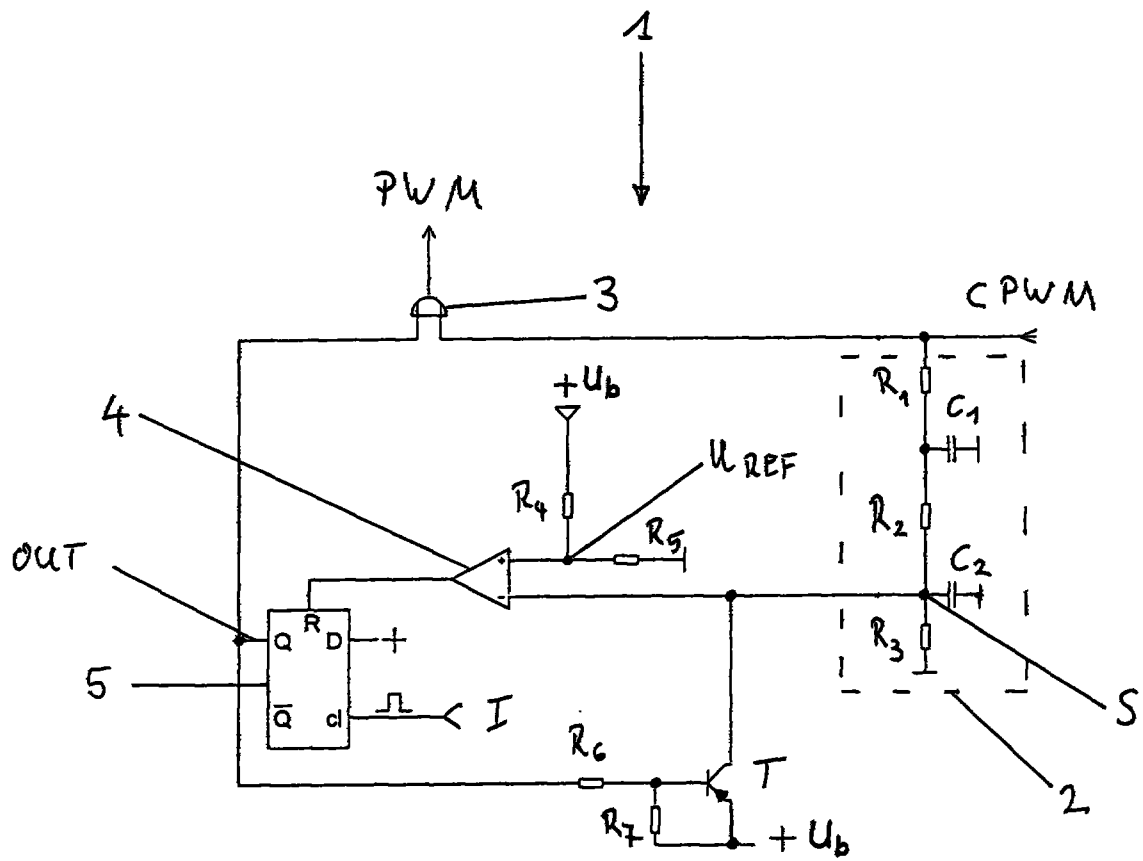
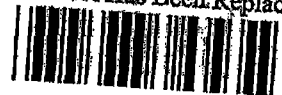
**List of reference symbols**

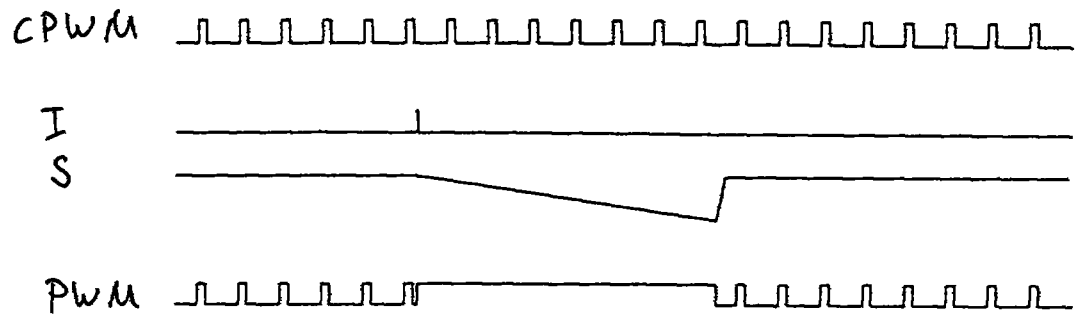
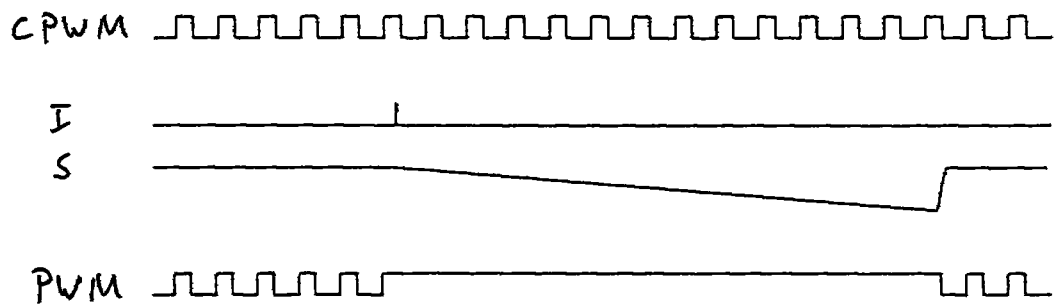
|                  |   |                       |
|------------------|---|-----------------------|
| 1                | - | Compensation circuit  |
| 2                | - | Integrator            |
| 3                | - | "OR" gate             |
| 4                | - | Comparator            |
| 5                |   | Flipflop              |
| T                | - | Transistor            |
| R <sub>1</sub>   | - | Resistor              |
| R <sub>2</sub>   | - | Resistor              |
| R <sub>3</sub>   | - | Resistor              |
| R <sub>4</sub>   | - | Resistor              |
| R <sub>5</sub>   | - | Resistor              |
| R <sub>6</sub>   | - | Resistor              |
| R <sub>7</sub>   | - | Resistor              |
| C <sub>1</sub>   | - | Capacitor             |
| C <sub>2</sub>   | - | Capacitor             |
| S                | - | Control signal        |
| I                | - | Commutation signal    |
| CPWM             | - | Motor control signals |
| U <sub>REF</sub> | - | Reference voltage     |
| OUT              | - | Flipflop output       |
| PWM              | - | Motor control signal  |

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Fig. 1

Fig. 2aFig. 2b

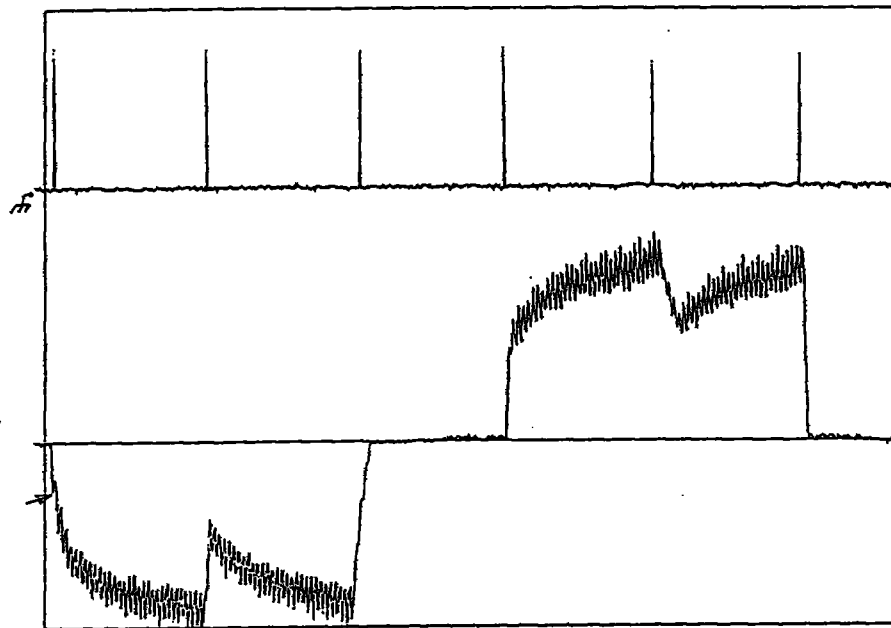


Fig. 3a

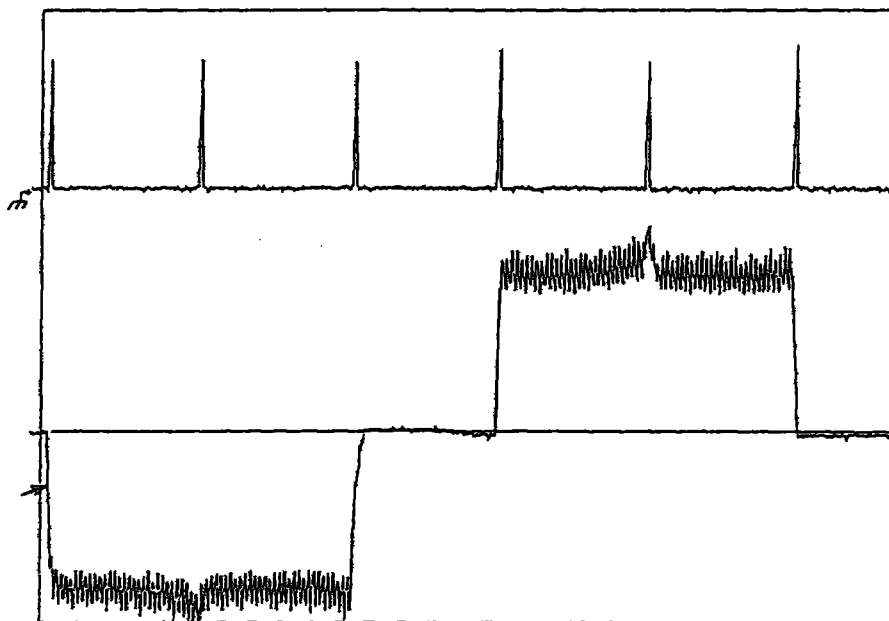


Fig. 3b

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**Motor controller for electronically commutated DC motors in  
order to compensate for torque drops**

The invention relates to a motor controller having  
5 electronic commutation which is connected to the windings  
of a motor, a predetermined additional current being  
connected to that coil of the motor which is active at that  
moment, from the commutation instant, in order to prevent  
torque drops.

10 US-4,511,827 discloses a controller which drives an  
electronically commutated motor such that torque  
fluctuations are suppressed. This device in this case  
comprises a sensor for determining the rotor position, in  
other words the commutation instant, and a controller which  
15 processes this signal so that the corresponding coil is  
supplied, from the commutation instant, with additional  
current in order to prevent a torque drop.

However, it has been found in the case of the known  
solution that the supply of a predetermined current to the  
20 coil compensates for the torque drops only within a  
specific motor current range. However, for example, in a  
video recorder, the known method does not provide  
satisfactory results since, in an operating mode (for  
example play or long-play), the currents may be very  
25 different because of different mechanical loads, for  
example in the case of different temperatures or cassettes.

The invention is thus based on the object of  
providing a motor controller in which torque drops are  
avoided even in the event of different motor loads.

30 The object is achieved by the features of  
Claim 1. Preferred refinements of the invention are  
specified in the subclaims.

According to the invention, in the case of a motor  
controller for electronically commutated DC motors, in  
35 which an additional current is connected to the active  
coil, from the commutation instant, in order to prevent  
torque drops, the duration and/or amplitude of the  
additional current pulse are/is determined as a function of  
the motor load. In other words, the duration and/or

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| <input checked="" type="checkbox"/> | Description | : paged 1.. to paged 1.. |
| <input checked="" type="checkbox"/> | Claim(s)    | : paged 1.. to paged 1.. |
| <input checked="" type="checkbox"/> | Drawing(s)  | : paged 1.. to paged 1.. |
| <input checked="" type="checkbox"/> | Abstract    | : paged 1.. to paged 1.. |

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amplitude of the additional current pulse are/is variable and are/is derived from the load on the motor, the additional current pulse being longer (greater) the higher the motor load, as is self-evident.

5           This advantageously results in torque drops being compensated for automatically and optimally, irrespective of the production scatter between motors, the temperature ranges and ageing.

10           The motor controller according to the invention normally controls the motor by means of so-called pulse-width modulation (CPWM or PWM) of the control pulses. The PWM signal of the motor controller is held at "1" for the duration of the additional current. The commutation instant, from which the additional current is applied, can  
15 be determined by a sensor.

          The motor load is determined from the motor current drawn, it being possible to determine the motor current, for example, by means of a measurement resistor which is connected in the motor circuit or from the ratio of the  
20 pulse duration to the pulse pause of the PWM signal.

          Furthermore, the controller according to the invention may have an integrator which produces a control signal (S) from the duty ratio of the CPWM signal. The start of the integration of the CPWM control signals is  
25 likewise brought about by the occurrence of the commutation signal.

          The controller advantageously has a flipflop whose Q output is connected to the CPWM control signals via an "OR" gate, so that the Q output is switched to logic "1" on  
30 the occurrence of the commutation signal, the Q output of the flipflop being reset again when the control signal corresponds with a reference voltage. The comparison between the reference voltage and the control signal is preferably carried out by means of a differential  
35 amplifier. This also brings about the end of the integration of the CPWM signals.

          A preferred embodiment of the invention will be explained in the following text with reference to the figures, in which:

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Fig. 1 shows a circuit diagram of the compensation section, according to the invention, of the motor controller,

Figs. 2a and 2b show timing diagrams of the input and output signals required for control purposes, and

Figures 3a and 3b show the current waveform in an electronically commutated motor, respectively without and with compensation.

Fig. 1 shows the logic circuit for compensating for torque drops in digitally driven, electronically commutated motors. A digital motor control signal CPWM, in which the motor load can be derived from the duty ratio, is passed to the input of the compensation circuit 1. A control signal S is derived from this signal CPWM by means of an integrator 2. The integrator 2 preferably comprises three serial resistors  $R_1$ ,  $R_2$  and  $R_3$ , as well as two capacitors  $C_1$  and  $C_2$ ,  $C_1$  being arranged electrically between earth (reference-earth potential) and the junction of  $R_1$  and  $R_2$ , and  $C_2$  being arranged electrically between earth and the junction of  $R_2$  and  $R_3$ , and the control signal S being formed on  $C_2$ . The control signal CPWM for controlling the motor, which is not illustrated, is furthermore passed to an input of an OR gate 3, so that a PWM control signal appears at the output of the OR gate 3 and is supplied to PWM power stages, which are likewise not illustrated, in order to provide the motor current in the individual motor coils or windings.

The control signal S which is produced by the integrator 2 is supplied to the inverting input of a differential amplifier which is designed as a comparator 4 and to whose non-inverting input a reference voltage  $U_{REF}$  is applied, which is defined via a voltage divider composed of resistors  $R_4$ ,  $R_5$ . The output of the comparator 4 is passed to the reset input of a flipflop 5, which is formed by a D flipflop. The D input of the flipflop 5 is at positive potential which can be derived, for example, from an operating voltage  $U_b$ . The occurrence of the commutation signal I for the motor drive activates the flipflop 5 via the clock input, so that a logic "1" appears at the Q output. The Q output of the flipflop 5 is passed to the

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other input of the OR gate 3. As a result of the CPWM signal being linked to the Q output by means of this OR circuit, the PWM signal for the power stages is in consequence held at logic "1" or at the "High" level, so  
5 that an additional current is supplied to the motor windings. The Q output of the flipflop 5 remains at logic "1" until logic "1" appears at the output of the comparator 4, so that the flipflop is reset via the reset input R of the flipflop 5 and, in consequence, a logic "0" appears at  
10 the Q output or the Q output is held at the "low" level. An npn transistor T is connected between the inverting input of the comparator 4 (control signal S) and the Q output of the flipflop 5, such that the base is connected to the Q output via a resistor  $R_6$ . The emitter of the transistor T,  
15 which is at the positive potential of the operating voltage  $U_b$ , is connected to the base via a resistor  $R_7$ , while the collector of transistor T is connected to the inverting input of the comparator 4. When the Q output of the flipflop 5 switches up to logic "1", the transistor T is  
20 switched off; while a logic "0" at the Q output of the flipflop 5 opens the transistor T, or switches it on.

The transistor T thus acts as an electronic switch by means of which the capacitor  $C_2$  on which the control signal S is formed can be charged to the positive potential  
25 of the operating voltage  $U_b$ , depending on the logic signal state at the Q output of the flipflop 5, or, when the Q output is switched to logic "0" or the "low" level, can be discharged to the potential which results on the capacitor  $C_1$  as a result of the continuous integration of the CPWM  
30 signals which are continuously supplied via the resistor  $R_1$ . The discharge time constant of the capacitor  $C_2$  is in this case essentially determined by the parallel circuit formed by the resistor  $R_3$  and the resistor  $R_2$ , the latter of which forms a series circuit with the capacitor  $C_1$  for  
35 discharging. The charging time constant of the capacitor  $C_2$  is determined by the resistance of the switched-on emitter-collector path through the transistor T.

Figures 2a and 2b show the waveform of the various control signals with respect to time, Fig. 2a illustrating

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the case when the motor load is low, and Fig. 2b illustrating the case when the motor load is high. The upper clock waveform in Fig. 2a shows the motor control signal CPWM, the duty ratio being relatively low. When the  
5 commutation signal I occurs, the Q output of the flipflop 5 is switched to the "High" level, so that the transistor T is switched off and defines the start of production of the control signal S. This means that the voltage on the capacitor  $C_2$ , which corresponds to the control signal S, in  
10 consequence falls until the flipflop 5 is reset via the R input. This results in the lower clock waveform at the output of the OR gate 3, that is to say the output of the OR gate 3 is logic "1" for the duration of the current control signal S, which means a positive potential with  
15 respect to the reference-earth potential in the present case, while logic "0" is, for example, the reference-earth potential.

Fig. 2b shows the same situation as Fig. 2a, but with the motor control signal CPWM having a higher duty  
20 ratio. As a result of the higher duty ratio of the motor control signal CPWM, the capacitor  $C_1$  is charged to a higher voltage in comparison with the situation according to Fig. 2a. The consequence of this is that the capacitor  $C_2$  is discharged more slowly and the waveform of the current  
25 control signal S also lasts for a longer time, so that the time period for which the output of the OR gate 3 remains at logic "1" is significantly longer.

Fig. 3a shows the current waveform in one of the motor windings without the compensation according to the  
30 invention for torque drops. The upper part illustrates the instants of commutation. The lower part shows the current waveform as a function of time. It can clearly be seen that drops occur in the current waveform and thus also in the torque waveform of a motor at the commutation instants.

35 In contrast to this, Fig. 3b shows the current waveform in one of the motor windings where current and/or voltage compensation are/is used in order to avoid torque drops. The current waveform, and thus the torque waveform

of the motor, is approximately constant at the commutation  
instants.

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## Patent Claims

1. Motor controller for electronically commutated DC  
5 motors, in which an additional current and/or voltage is  
connected to the active motor winding from the commutation  
instant in order to prevent torque drops, characterized in  
that the duration and/or amplitude of the additional  
current and/or voltage pulse is derived from the motor  
10 load.
2. Motor controller according to Claim 1,  
characterized in that the motor is driven by pulse-width  
modulation (PWM).
3. Motor controller according to Claim 2,  
15 characterized in that the PWM signal is held at logic "1"  
for the duration of the additional current and/or voltage.
4. Motor controller according to one of the preceding  
claims, characterized in that the commutation instant is  
determined by a sensor.
- 20 5. Motor controller according to one of the preceding  
claims, characterized in that the motor load is determined  
from the motor current drawn.
6. Motor controller according to Claim 5,  
characterized in that the motor current is determined by a  
25 measurement resistor in the motor circuit.
7. Motor controller according to Claim 4,  
characterized in that the motor current is determined from  
the ratio of the pulse duration to the pulse pause in the  
PWM signal and/or from the motor rotation speed.
- 30 8. Motor controller according to Claim 7,  
characterized in that the controller has an integrator (2)  
which produces a control signal (S) from the duty ratio of  
the PWM signal.
9. Motor controller according to Claim 8,  
35 characterized in that the controller furthermore has a  
flipflop (5) whose Q output together with the PWM control  
signal form the inputs of an OR gate, so that the Q output  
is switched to logic "1" on the arrival of the commutation  
signal (I), and the Q output is reset again when the

control signal (S) corresponds with a reference voltage ( $U_{REF}$ ).

10. Motor controller according to Claim 9, characterized in that the comparison between the reference  
5 voltage ( $U_{REF}$ ) and the control signal (S) is carried out by means of a differential amplifier (4).



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MOTOR CONTROLLER FOR ELECTRONICALLY COMMUTATED DC MOTORS IN  
ORDER TO COMPENSATE FOR TORQUE DROPS

**Abstract**

In the case of a motor controller for electronically commutated DC motors, an additional current and/or an additional voltage is passed at the commutation instant to that winding of the motor which is active at that time, in order to prevent torque drops. In order to compensate for torque drops at different motor loads, the duration and/or amplitude of the additional current and/or of the additional voltage are/is determined from the actual motor load.

[Fig.1]

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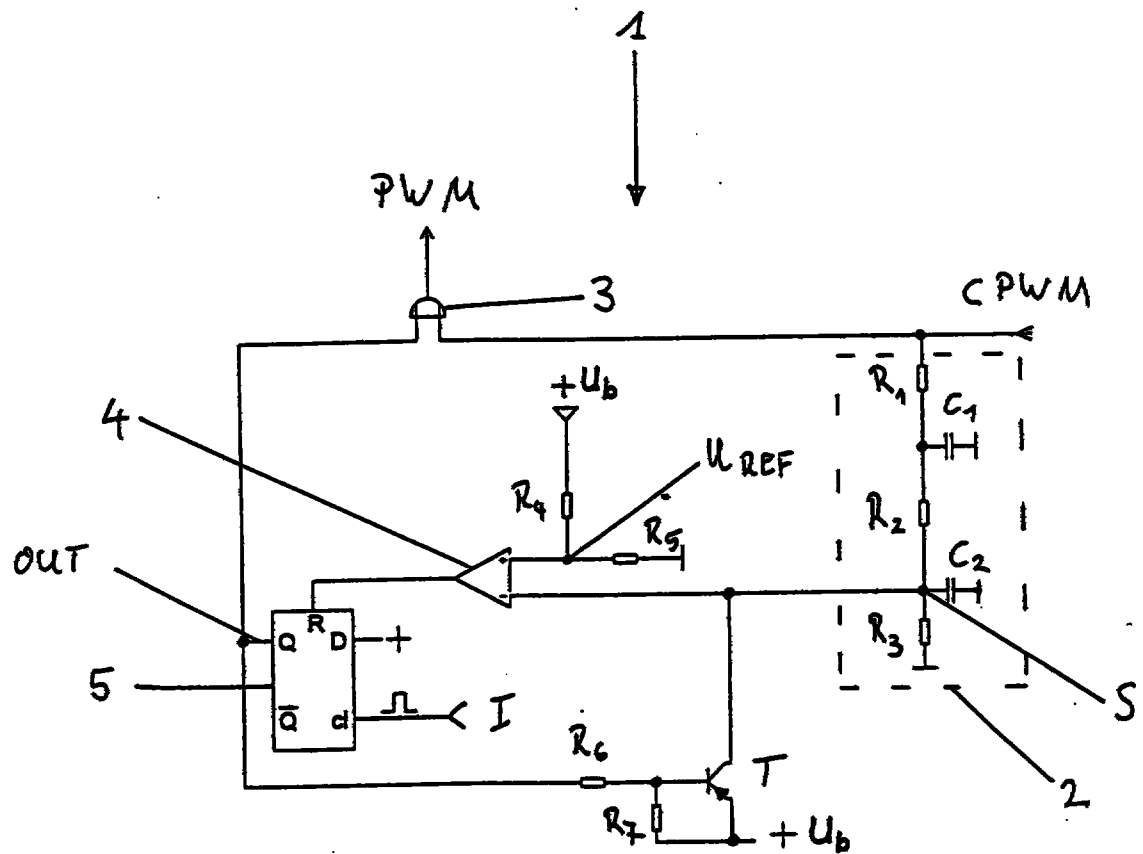
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## List of reference symbols

|                  |   |                       |
|------------------|---|-----------------------|
| 1                | - | Compensation circuit  |
| 2                | - | Integrator            |
| 3                | - | "OR" gate             |
| 4                | - | Comparator            |
| 5                | - | Flipflop              |
| T                | - | Transistor            |
| R <sub>1</sub>   | - | Resistor              |
| R <sub>2</sub>   | - | Resistor              |
| R <sub>3</sub>   | - | Resistor              |
| R <sub>4</sub>   | - | Resistor              |
| R <sub>5</sub>   | - | Resistor              |
| R <sub>6</sub>   | - | Resistor              |
| R <sub>7</sub>   | - | Resistor              |
| C <sub>1</sub>   | - | Capacitor             |
| C <sub>2</sub>   | - | Capacitor             |
| S                | - | Control signal        |
| I                | - | Commutation signal    |
| CPWM             | - | Motor control signals |
| U <sub>REF</sub> | - | Reference voltage     |
| OUT              | - | Flipflop output       |
| PWM              | - | Motor control signal  |

This is the replacement sheet

Date: 24 DEC 1996

Fig. 1

This is the replacement sheet

Date: 24 DEC 1996

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2.

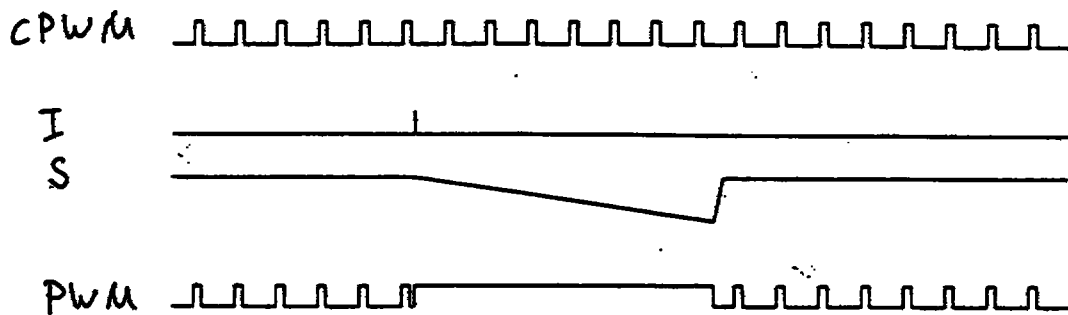


Fig. 2a

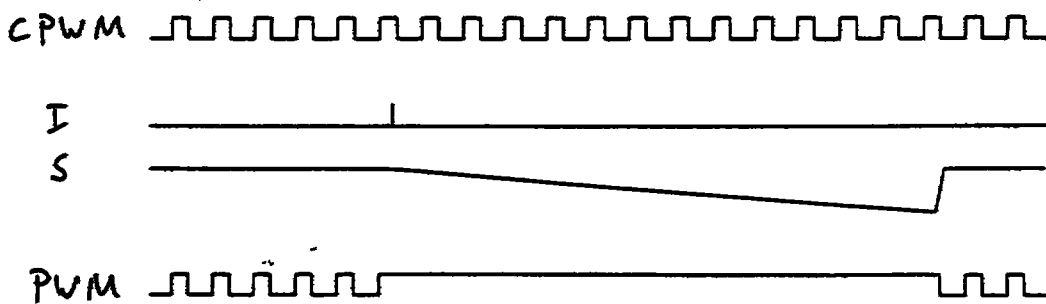


Fig. 2b

This is the replacement sheet

Date: 24 DEC 1996

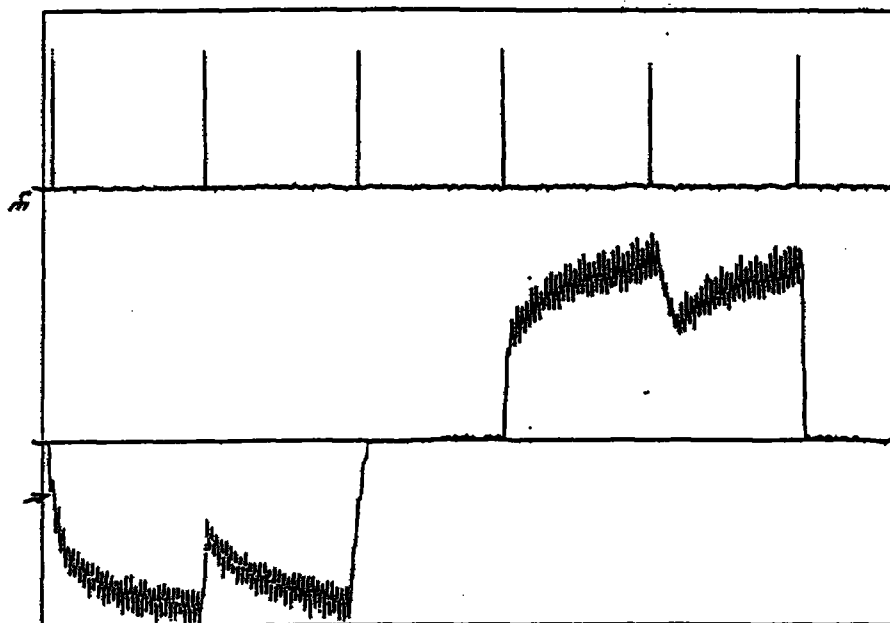


Fig. 3a

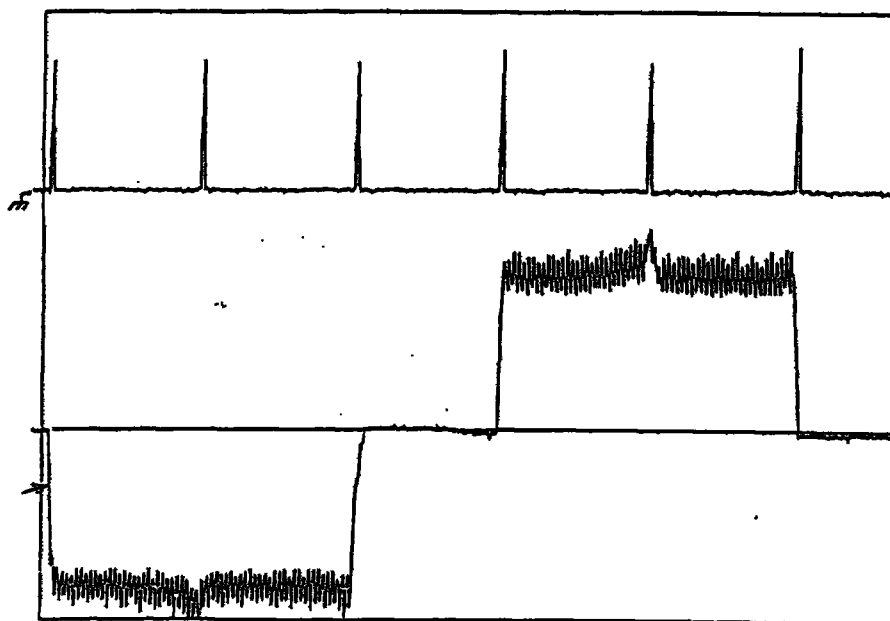


Fig. 3b

This is the replacement sheet

Date: 24 DEC 1996