

PATENT SPECIFICATION

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- (21) Application No. 26700/73 (22) Filed 5 June 1973
 (31) Convention Application No. 61 794/72 (32) Filed 22 June 1972 in
 (33) Japan (JA)
 (44) Complete Specification published 10 March 1976
 (51) INT. CL.² H02P 7/00 // 5/16
 (52) Index at acceptance
 H2J 12H2 12M 12N1 12N3B 12N3Y 12N4 12NX 14X
 G3R 112E 33D2P 4 61 72N 72Y 73 74 8W



(54) AN OPERATING CIRCUIT FOR A BRUSHLESS ELECTRIC MOTOR

- (71) We, KABUSHIKI KAISHA SUWA SEIKOSHA and SHINSHU SEIKI KABUSHIKI KAISHA, both Japanese bodies corporate, of 3-4, 4-chome, Ginza, Chuo-ku, Toyko, Japan and 3-5, 3-chome, Owa, Suwa-shi, Nagano-ken, Japan, respectively, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—
- This invention relates to control circuits for brushless electric motors.
- According to one aspect of the present invention there is provided an operating circuit for a brushless electric motor which includes a rotor and one or more driving coils, the operating circuit comprises a flux detecting circuit for detecting the magnetic flux of the rotor and for producing an electrical signal therefrom; a driving circuit for amplifying the electrical signal from the detecting circuit and for apply and the amplified electrical signal to the or each driving coil and a control circuit for controlling rotation of the motor by applying a control signal to the detecting circuit or to the driving circuit, said control circuit including only one transistor, a pre-determined voltage generating circuit consisting of a voltage regulating device in parallel with a potential divider and a speed detecting circuit for producing an electrical signal which is proportional to the speed of rotation of the rotor, said speed detecting circuit being non-inductively connected between either the driving coils or separate detecting coils and the voltage regulating device.
- The flux detecting circuit preferably includes at least one Hall effect device for detecting the magnetic flux.
- The voltage regulating device may be a zener diode.
- The driving circuit, in one embodiment,

consists of a pair of transistors connected in push-pull configuration.

Preferably the control circuit includes temperature compensating means for compensating for the effects of temperature changes on the operating point of said one transistor. The temperature compensating means may be a thermistor.

In the preferred embodiment, the potential divider may include a variable resistor.

According to one further aspect of the present invention there is provided a brushless electric motor having an operating circuit as recited above.

The invention is illustrated, merely by way of example in the accompanying drawings, in which:—

Figure 1 illustrates a conventional operating circuit for a brushless electric motor;

Figure 2 shows one embodiment of an operating circuit according to the present invention for a brushless electric motor; and

Figure 3 shows another embodiment of an operating circuit according to the present invention for a brushless electric motor.

Referring first to Figure 1 a conventional operating circuit for a brushless electric motor is shown. The operating circuit includes Hall effect devices 1, 11 made, for example, of indium antimonide and resistors 8, 18 for controlling the current to the Hall effect devices. The Hall effect devices 1, 11 and the resistors 8, 18 constitute a detecting circuit for detecting the magnetic flux in driving coils 4, 5, 14, 15 and for producing an electrical signal therefrom.

The Hall effect devices are connected to the bases of driving transistors 2, 3 and 12, 13 respectively, the driving transistors amplifying the electrical signal from the detecting circuit and providing a driving signal which is applied to the driving coils 4, 5, 14, 15. The driving transistors 2, 3, 90

12, 13 and the driving coils 4, 5, 14, 15 constitute a driving circuit which drives a rotor (not shown) made of permanently magnetic material, of the brushless electric motor.

Diodes 6, 7, 16, 17 produce an electrical speed signal, proportional to the speed of rotation of the rotor, from the driving coils 4, 5, 14, 15. The speed signal is amplified by a transistor 20. A control signal fed to the Hall effect devices 1, 11 is determined by controlling the base voltage of a transistor 19. Thus by determining the control signal to the Hall effect devices the speed of rotation of the rotor can be controlled. A potential divider, composed of resistors 23, 24 divides the speed signal, and a voltage from the centre point of the potential divider is smoothed by a capacitor 26 and is applied to the base of the transistor 20. A voltage determined by the resistance of the resistor 23 and a variable resistor 22 is also applied to the base of transistor 20, the resistors 22, 23 being in series with a power source (not shown) connected across terminal 27, 28. A thermistor 25 is provided to compensate for temperature changes affecting the operating points of the transistors 19, 20, since otherwise the operating points of the transistors 19, 20 would vary with changes in temperature and the speed of rotation of the rotor would alter. A load resistor 21 is connected to the collector of the transistor 20. As will be appreciated the variable resistor 22 determines, in part, the voltage applied to the base of the transistor 20 and by varying the resistance of the variable resistor 22 the speed of rotation of the rotor can be changed. The diodes 6, 7, 16, 17, the transistors 19, 20, the resistors 21, 22, 23, 24, the thermistor 25 and the capacitor 26 constitute a control circuit 100.

Since the main components of the control circuit 100 are the two transistors 19, 20 and since it is difficult to determine accurately the operating points of the transistors, the operating range, and consequently the control range, of the conventional operating circuit is narrow. The control characteristics of the conventional operating circuit tends to be poor if the voltage of the power source varies over a wide range. Since the control circuit 100 employs two transistors 19, 20 the voltage V_{BE} between the base and the emitter and the switching current I_{CBO} thereof are both affected by temperature changes to such an extent that it is difficult to compensate using a thermistor. When the conventional operating circuit 100 is mass-produced transistors may be used on which the desired compensation for temperature changes cannot be performed.

The embodiments of the present in-

vention described hereinafter do not have the defects of the conventional operating circuit.

Referring to Figure 2 there is shown an operating circuit according to the present invention. The operating circuit includes a Hall effect device 31 and a resistor 38 for controlling the current to the Hall effect device. The Hall effect device and the resistor 38 constitute a flux detecting circuit for detecting the magnetic flux in driving coils 34, 35 and for producing an electrical signal therefrom.

Driving transistors 32, 33 amplify the electrical signal from the detecting circuit and provide a driving signal which is applied to the driving coils 34, 35. The driving transistors 32, 33, connected in push-pull configuration and the driving coils 34, 35, constitute a driving circuit.

Diodes 36, 37 constitute a speed detecting circuit to produce an electrical speed signal, proportional to the speed of rotation of a rotor (not shown) of the brushless electric motor, from the driving coils 34, 35. The diodes 36, 37 are non-inductively connected between drawing coils 34, 35 respectively and a zener diode 40. The voltage across a resistance 43, which is connected to the base of a transistor 39, is maintained constant by the zener diodes even when the voltage of a power source (not shown) connected across terminals 46, 47 varies. A resistor 41 determines the voltage applied to the zener diode 40, the voltage from which is divided by a potential divider consisting of a variable resistor 42 and the resistor 43. A thermistor 44 is connected in parallel with the resistor 43 for compensating the changes of temperature affecting the operating point of the transistor 39 and the zener diode 40. The variable resistor 42 is arranged to control the base voltage applied to the transistor 39. The resistance of the variable resistor 42, therefore, determines the speed of rotation of the rotor. The transistors 39, the diodes 36, 37, the zener diode 40, the resistors 41, 42, 43, the thermistor 44 and a capacitor 45 constitute a control circuit 200 which produces a control signal which is applied to the Hall effect device 31 to determine the speed of rotation of the rotor. Moreover, the zener diode 40, the resistors 42, 43 and the thermistor 44 constitute a predetermined voltage generating circuit.

The speed signal produced by the diodes 36, 37 and smoothed by the capacitor 45 is supplied to the emitter of the transistor 39. Consequently, the potential of the emitter of the transistor 39 is biased to a positive potential. The transistor 39 is actuated by the difference between the voltage across the resistor 43 produced by the zener

diode 40 and the voltage across the capacitor 45.

The rotation of the rotor is controlled as follows by the above operating circuit. If the rotational speed of the rotor increases above a predetermined speed, the voltage across the capacitor 45 increases. Since the voltage across the resistor 43 is constant because it is produced by the zener diode, the voltage between the base and emitter of the transistor 39 is reduced. Accordingly, the current of the control signal applied to the Hall effect device 31 is reduced, and the current flowing through the driving coils 36, 37 is correspondingly reduced. Consequently, the rotation of the rotor decreases to the predetermined speed.

Since the main components of the control circuit 200 is a single transistor 39 and a zener diode, control of the operating point of the transistor is very simple. Since the transistor 39 is controlled by the signal which is proportional to the speed of rotation of the rotor, the operating range and consequently the control range of the transistor is extended. Since the voltage produced by the zener diode is used to determine the speed of rotation the rotor speed can be maintained at the predetermined speed even though the voltage of the power source varies over a relatively wide range. Further, compensation for variation in the speed of rotation of the rotor from the predetermined speed due to temperature changes affecting the operating point of the transistor 39, is better than in the conventional operating circuit having two transistors. Consequently, the operating circuit shown in Figure 2 may be mass-produced, and has quite excellent control characteristics and high stability. Furthermore, the operating circuit of Figure 2 can be simplified and miniaturised, so that a brushless electric motor having such an operating circuit can be manufactured easily and its cost can be lower compared with the cost of manufacturing a brushless electric motor having the conventional operating circuit.

Referring now to Figure 3 another embodiment of an operating circuit according to the present invention for a brushless electric motor is shown. The operating circuit includes a Hall effect device 51 and resistors 58, 59 for controlling the current of the Hall effect device 51. The Hall effect device and the resistors 58, 59 constitute a detecting circuit for detecting the magnetic flux in driving coils 54, 55 and producing an electrical signal therefrom.

Driving transistors 52, 53 connected in push-pull configuration, amplify the electrical signal from the detecting circuit and provide a driving signal which is applied to the driving coils 54, 55. The driving trans-

istors 52, 53 and the coils 54, 55 constitute a driving circuit.

Detecting coils 56, 57 together with respective diodes 60, 61 constitute a speed detecting circuit to produce an electrical speed signal proportional to the rotational speed of a rotor (not shown) of the brushless electric motor. The diodes 60, 61 are non-inductively connected between the detecting coils 56, 57 respectively and a zener diode 63. The signal from the coils 56, 57 and the diodes 60, 61 is smoothed by a capacitor 68, and supplied to the emitter of a transistor 62, so that the emitter of the transistor 62 is biased to a positive potential. A resistor 64 determines the voltage applied to the zener diode 63. A variable resistor 65 is connected in series with a resistor 66 to form a potential divider which divides the voltage from the zener diode. A thermistor 67 which is connected in parallel with the resistor 66 compensates for temperature changes affecting the operating point of the transistor 62. The rotational speed of the rotor is determined by the resistance of the variable resistor 65. A capacitor 69 is connected to the common point of the resistors 65, 66 and to collector of the transistor 62 to prevent self-oscillation. The detecting coils 56, 57, the diodes 60, 61, the transistor 62, the zener diode 63, the resistors 64, 65, 66, the thermistor 67, and the capacitors 68, 69 constitute a control circuit 300. Moreover, the zener diode 63, the resistors 65, 66 and the thermistor 67 constitute a predetermined voltage generating circuit. The control circuit produces a driving signal which is applied to the driving coils 54, 55 to determine the speed of rotation of the rotor.

The rotational speed of the rotor is controlled by the above operating circuit as follows. If the rotational speed of the rotor increases above a predetermined speed, the voltage across the capacitor 68 increases. Since the voltage across the resistor 66 is constant, the voltage between the base and emitter of the transistor 62 is reduced and the voltage to the emitters of transistors 52, 53 of the driving circuit increases. Consequently, the voltage between the base and the emitter of each transistor 52, 53 is reduced and the driving signal applied to the driving coils 54, 55 is correspondingly reduced. As a result, the rotational speed of the rotor will decrease until it reaches the predetermined speed.

As with the control circuit 200 of Figure 2 the control characteristics of the control circuit 300 are improved and the circuit is stable and simple in construction. The operating circuit of Figure 3, therefore, may be miniaturised and its manufacturing cost reduced.

The control circuits described in connection with Figures 2 and 3 each employ a single Hall effect device. Further, the transistors 39, 62 are free from the polarity structure.

As mentioned above, the operating circuits according to the present invention and described above, are designed to be used in connection with brushless electric motors, have excellent control characteristics, are simple in construction and may be made of small size. Consequently, a brushless electric motor having an operating circuit according to the present invention may be manufactured easily and at relatively low cost.

WHAT WE CLAIM IS:—

1. An operating circuit for a brushless electric motor which includes a rotor and one or more driving coils, the operating circuit comprising a flux detecting circuit for detecting the magnetic flux of the rotor and for producing an electric signal therefrom, a driving circuit for amplifying the electrical signal from the detecting circuit and for applying the amplified electrical signal to the or each driving coil and a control circuit for controlling rotation of the motor by applying a control signal to the detecting circuit or to the driving circuit, said control circuit including only one transistor, a predetermined voltage generating circuit consisting of a voltage regulating device in parallel with a potential divider, and a speed detecting circuit for producing an electrical signal which is proportional to the speed of rotation of the rotor, said speed detecting circuit being non-in-

ductively connected between either the driving coils or separate detecting coils and the voltage regulating device.

2. An operating circuit as claimed in claim 1 in which the detecting circuit includes at least one Hall effect device for detecting the magnetic flux.

3. An operating circuit as claimed in claim 1 or 2 in which the voltage regulating device is a zener diode.

4. An operating circuit as claimed in any preceding claim in which the driving circuit consists of a pair of transistors connected in push-pull configuration.

5. An operating circuit as claimed in any preceding claim in which the control circuit includes temperature compensating means for compensating for the effects of temperature changes on the operating point of said one transistor.

6. An operating circuit as claimed in claim 5 in which the temperature compensating means is a thermistor.

7. An operating circuit as claimed in any preceding claim in which the potential divider includes a variable resistor.

8. An operating circuit for a brushless electric motor substantially as herein described with reference to Figure 2 or Figure 3 of the accompanying drawings.

9. A brushless electric motor having an operating circuit as claimed in any preceding claim.

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WHAT WE CLAIM IS:—

1. An operating circuit for a brushless electric motor which includes a rotor and one or more driving coils, the operating circuit comprising a flux detecting circuit for detecting the magnetic flux of the rotor and for producing an electric signal therefrom, a driving circuit for amplifying the electrical signal from the detecting circuit and for applying the amplified electrical signal to the or each driving coil and a control circuit for controlling rotation of the motor by applying a control signal to the detecting circuit or to the driving circuit, said control circuit including only one transistor, a predetermined voltage generating circuit consisting of a voltage regulating device in parallel with a potential divider, and a speed detecting circuit for producing an electrical signal which is proportional to the speed of rotation of the rotor, said speed detecting circuit being non-in-

ductively connected between either the driving coils or separate detecting coils and the voltage regulating device.

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