

PATENT SPECIFICATION

(11) 1273891

DRAWINGS ATTACHED

- (21) Application No. 10926/70 (22) Filed 6 March 1970
 (31) Convention Application No. 16498 (32) Filed 6 March 1969 in
 (33) Japan (JA)
 (45) Complete Specification published 10 May 1972
 (51) International Classification H02K 29/02//H02P 5/16
 (52) Index at acceptance

H2A 1C13 24
 G3R 112A 33D2Q 33DX 4 72



(54) DRIVING CIRCUIT FOR A BRUSHLESS MOTOR

(71) We, KABUSHIKI KAISHA SUWA SEIKOSHA, a Japanese company, of 3-4, 4-chome, Ginza, Chuo-ku, Tokyo, Japan, 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 brushless motor and driving circuit arrangements.

The invention will be described, merely by way of example, with reference to the accompanying drawings, wherein,

Figure 1 shows a typical known driving circuit for a brushless motor.

Figure 2 is a block diagram of an embodiment of this invention,

Figure 3 is a circuit diagram of the embodiment of Figure 2, and

Figure 4 is a circuit diagram of a modification according to the invention.

There are several known types of arrangement for detecting the position and/or rotational speed of a motor rotor without using an electro-mechanical commutator, e.g. by detecting radiation energy using a photo-transistor; or by detecting magnetic energy using a shield of magnetic material and a magnetic detector or by using means in which a self oscillating semi-conductor circuit is started and stopped electrically. In one known way of carrying out the last method, a shield disc having a cut-away portion is attached coaxially to the rotor shaft and is used to detect rotor position by starting or stopping the oscillator. If the shield disc is placed in the gap between the two oscillator coils the Q value of the two coils falls and the electrical oscillation stops. If the cut-away portion of the shield disc comes between the two oscillator coils, the Q value of the two coils increases and electrical oscillation starts. The oscillation so produced is converted to a drive signal by a demodulating circuit and this is amplified and fed to the driving coil of the motor. The shape of the shield disc is such that it permits only one of several oscillators—

there is one for each phase of the motor winding—to be energised at one time, the oscillators being energised sequentially to rotate the motor.

Figure 1 shows a conventional driving circuit of this nature for a three phase motor.

There are provided oscillators 1, 2, 3 having respective pairs of oscillator coils 10, 11; 12, 13; 14, 15. A slotted disc 25 having three slots is driven by motor 24 and is disposed between the coils of each pair. When a slot of the disc 25 is disposed between a pair of coils, the oscillator of which they form part is activated. The oscillator signal so produced is demodulated into a D.C. drive signal in a demodulator 4, 5 or 6 and amplified in a power amplifier 7, 8 or 9. It is then fed to a motor driving coil 16, 17 or 18. Energisation of the driving coils is effected sequentially, due to the arrangement of the oscillator coils and the slots in the disc, and thus the motor 24 is rotated. The speed of rotation is sensed by a coil 23 and speed control is effected via diodes 19, 20, 21.

In the Figure 1 circuit each oscillator is repeatedly started or stopped by the disc 25. If the ambient temperature and the supplied voltage are changed, it is difficult to stabilise the oscillators due to the transient nature of the operation. As a result, the oscillators do not operate consistently and the motor does not operate in stable condition.

Furthermore, in the Figure 1 circuit n oscillators are required for an n-phase driving motor, that is to say many circuit elements are necessary. Thus, in the conventional driving circuit of Figure 1, the circuit components required are:

Transistors	9
Condensers	18
Resistors	18
Diodes	6

The present invention seeks to provide improved brushless motor and driving circuit arrangements which shall not only avoid the

[Price 25p]

Price 33p

defects of instability of operation and multiplicity of parts of the known arrangement of Figure 1, but shall also have the important advantages of lightness of weight of moving parts and freedom from mechanical asymmetry of moving parts. The latter is particularly important for high speed motors, for such asymmetry, especially if the parts in question are heavy, will cause serious parasitic oscillation.

According to this invention a brushless motor and driving circuit arrangement comprises a motor having a rotor and a plurality of driving coils; a rotor position detecting means including a like plurality of pairs of substantially co-axially arranged and axially spaced coils, one coil of each pair being a transmitting coil and the other being a receiving coil and a rotary disc of non-magnetic electrically conductive material driven by said motor to rotate in a plane passing between the coils of the pairs; a continuously operating radio frequency oscillator connected to supply radio frequency oscillations to the transmitting coils; and means for utilising signals coupled into the receiving coils from the transmitting coils for supplying driving current to the driving coils, said disc being so constructed and shaped as to act, in rotation, to provide interrupted eddy current shielding between the transmitter coils and their associated receiver coils allowing the coils of each pair successively to be unshielded from each other.

Preferably the disc is provided with at least one gap in its periphery whereby an opening comes between each of the pairs of coils in succession.

Figures 2 to 4 illustrate embodiments including a continuously running radio frequency oscillator the output from which is modulated by a rotating slotted disc, the modulated signals being subsequently demodulated and used to provide drive signals.

Referring to Figure 2, the oscillator 30 is provided with transmitter coils 31, 32, 33, and there is a receiver coil 34, 35, 36 for each driving coil of the motor. When a slot in a rotating disc 46 driven by a motor 47 registers with a receiver coil, e.g. 34, and a transmitter coil, e.g. 31, the receiver coil receives an RF oscillator output signal. When no slot registers, no RF signal is received. Thus, the oscillator signal received by the receiver coil is modulated in that it is present only intermittently.

The modulation of the received oscillator signal is due to flux generated by the transmitting coil interlinking with the receiving coil at the slotted portion of the disc 25 and inducing a voltage in the receiving coil. When the disc 25 extends into the gap between the transmitting coil and the receiving coil, the magnetic flux is shielded by eddy

currents in the disc 25 and a voltage is not induced in the receiving coil.

Parts 37, 38 and 39 are amplifiers and demodulators which amplify and demodulate the signal received in the receiving coils 34, 35 and 36. The demodulated D.C. signal is fed to power amplifying motor driving circuits 40, 41, 42, each comprising switching transistors and which supply drive signals to driving coils 43, 44 and 45 of the motor 47. A speed control coil 48 senses the speed of rotation of the motor, and a speed control circuit 49 controls the driving circuits 40, 41, 42 in response thereto. The frequency of the oscillator circuit 30 is very high compared to the rotation frequency of the motor 47.

Since the oscillator is continuously operating, the circuit can be stabilised easily by variation of the operating point even when subjected to a change in supplied voltage and ambient temperature, as the feedback ratio of the oscillating circuit may be made large. The oscillator (transmitter) coils can be connected either in series (as shown in Figure 2) or in parallel in a common oscillating circuit.

Since the oscillator 30 is common to all three transmitting coils 31, 32, 33, this reduces the number of components. However, a separate oscillator may be provided for each coil 31, 32, 33 if desired; the advantage of stability mentioned above will still be obtained.

Although in the Figure 2 embodiment the voltage induced in the coil 48 by the rotation of the motor 47 is used for speed control, any of a variety of other speed control methods or arrangements known per se, may be used. For example, the frequency of modulation of the oscillator output may be detected to control motor speed. also, especially if the load on the motor is constant, a speed control system may not be necessary at all.

In a preferred electrical speed control, a signal from the coil 48 is rectified and applied as feedback to the driving circuit. This may be done by controlling the output of the receiver coils or the output of the demodulators or the outputs of the power amplifiers.

Where an integrated circuit arrangement comprising transistor and resistor elements is used, it is more convenient to apply the feedback to control the oscillator output when the control circuit 49 has a transistor connected in series (cascade) with the oscillating transistor.

In a mechanical control system utilising mechanical contact points on the rotor shaft, the impulses so produced may be amplified by the circuit 49 to control the motor speed.

Figure 3 shows a circuit diagram of the apparatus of Figure 2. The oscillator comprises a transistor 51, condensers 52, 53 and 54, resistors 55 and 83 and transmitting coils 56, 57 and 58. Radio frequency transmitted oscillator outputs from the coils 56,

57, 58 are sequentially modulated by a slotted disc 84 equivalent to the disc 46 of Figure 2. The modulated oscillator output signals are respectively received by receiving coils 59, 60 and 61 and are amplified by demodulating and amplifying transistors 62, 63, 64 across the base and emitter terminals of which the receiving coils are connected. The amplified demodulated signals pass through the resistors 65, 66 and 67 into the base terminals of power amplifying transistors 77, 78 and 79 which provide drive signals to motor driving coils 74, 75 and 76. The three condensers 71, 72 and 73 connected between the base and collector electrodes of the transistors 77, 78, 79 serve as integrating condensers and prevent parasitic oscillation produced by stray capacity between the driving coils 74, 75, 76 and the transistors 77, 78, 79.

A voltage induced in a speed detecting coil 81 as a result of rotation of the motor 80 is fed to a speed control circuit 82. If the motor speed varies, the induced voltage operates so as to adjust the signal fed to the base electrodes of the transistors 77, 78 and 79, by means of diodes 68, 69, 70 so as to maintain the motor speed constant.

Figure 4 shows an improved form of the Figure 3 circuit, in which pre-amplifying transistors 90, 91 and 92 for amplifying the modulated oscillator output signals are connected to power amplifying transistors 96, 97 and 98 by means of compound connection, that is to say the collector-emitter paths of the transistors 90, 91, 92 are connected between the collector and base electrodes of the power amplifying transistors 96, 97, 98. Condensers 93, 94 and 95 are connected between the collector and base electrodes of the transistors 96, 97, 98 for demodulation, in co-operation with the transistors 90, 91 and 92, and for preventing parasitic oscillation. The other components operate the same as in the circuit of Figure 3. The number of components in the present embodiment is very small compared with the Figure 1 circuit. Thus, the component totals are:

Transistors:	7
Condensers:	6
Resistors:	5
Diodes:	3

In the Figure 3 and 4 embodiments, various modifications may be made. For example, receiving coils 99, 100 and 101 in Figure 4 may be connected between the bases of the transistors 90, 91, 92 and earth. However, the illustrated embodiment has the advantage that the transistors 90, 91, 92 will operate from a very small received signal. Condensers 93, 94 and 95 may be connected between the bases of the transistors 96, 97 and 98 and earth. But in the illustrated embodiment, condensers of smaller capacity may be used and the elec-

tric circuit is reduced in size. In the Figure 4 embodiment, the transistors 90, 91 and 92 are used to amplify and demodulate the modulated oscillator output signals. However, when the received signal has sufficient energy, the demodulating circuit may consist of passive elements such as resistors, condensers and diodes.

Alternative points to which the speed controller may supply its feedback signal are a, b, c, and (d, e, f) in Figure 4.

WHAT WE CLAIM IS:—

1. A brushless motor and driving circuit arrangement comprising a motor having a rotor and a plurality of driving coils; a rotor position detecting means including a like plurality of pairs of substantially co-axially arranged and axially spaced coils, one coil of each pair being a transmitting coil and the other being a receiving coil and a rotary disc of non-magnetic electrically conductive material driven by said motor to rotate in a plane passing between the coils of the pairs; a continuous operating radio frequency oscillator connected to supply radio frequency oscillations to the transmitting coils; and means for utilising signals coupled into the receiving coils from the transmitting coils for supplying driving current to the driving coils, said disc being so constructed and shaped as to act, in rotation, to provide interrupted eddy current shielding between the transmitter coils and their associated receiver coils allowing the coils of each pair successively to be unshielded from each other.

2. An arrangement as claimed in claim 1 wherein the disc is provided with at least one gap in its periphery whereby an opening comes between each of the pairs of coils in succession.

3. An arrangement as claimed in claim 1 wherein each receiving coil feeds into a demodulating transistor amplifier followed by a transistor power amplifier feeding a driving coil of the motor.

4. An arrangement as claimed in any of the preceding claims and including speed regulating means operating to control the speed of the motor by controlling amplifiers fed from the receiving coils.

5. An arrangement as claimed in any of the preceding claims wherein a demodulating transistor amplifier associated with each receiving coil has the emitter and base electrodes of a transistor therein connected across the associated receiving coil.

6. An arrangement as claimed in claim 1, wherein the collector-emitter path of a transistor in a demodulating transistor amplifier associated with each receiving coil is connected between the collector electrode and the base electrode of a following power amplifying transistor.

7. Brushless motor and driving circuit arrangements substantially as herein described with reference to Figures 2 to 4 inclusive of the accompanying drawings.

J. MILLER & CO.,
Agents for the Applicants,
Chartered Patent Agents,
262 High Holborn,
London, W.C.1.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1972.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from
which copies may be obtained.

