

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
6 April 2006 (06.04.2006)

PCT

(10) International Publication Number
WO 2006/036201 A1

(51) International Patent Classification:

H02K 21/24 (2006.01) *H02K* 29/08 (2006.01)
H02K 3/26 (2006.01) *H02P* 6/00 (2006.01)

(21) International Application Number:

PCT/US2005/011583

(22) International Filing Date: 5 April 2005 (05.04.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:

10/942,505 16 September 2004 (16.09.2004) US

(71) Applicant (for all designated States except US): **TRIMBLE NAVIGATION LIMITED** [US/US]; 749 North Mary Avenue, Sunnyvale, CA 94085 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): **ZALUSKY, James, Thomas** [US/US]; 2185 South Tulane Drive, Beavercreek, OH 45431 (US).

(74) Agents: **SWANSON, Kristina, E.** et al.; Dinsmore & Shohl LLP, Suite 1300, One South Main Street, Dayton, OH 45402 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

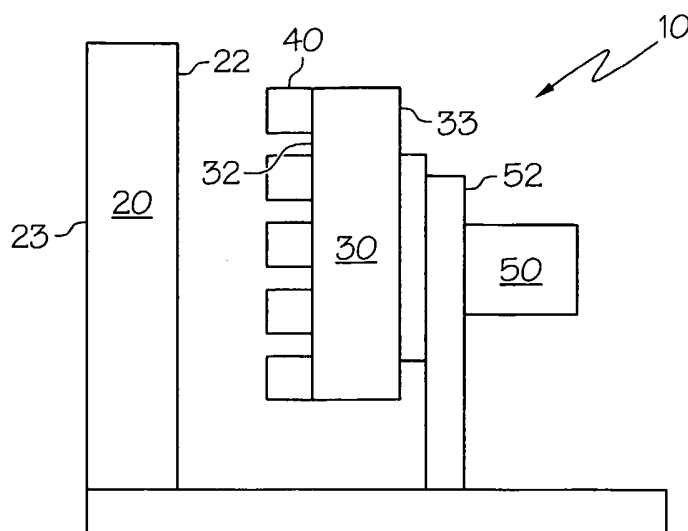
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: PRINTED CIRCUIT BOARD MOTOR AND CONTROL SCHEME



(57) Abstract: A printed circuit board motor is disclosed. The motor (10) comprises a rotor plate (31) embedded with magnets (40), an axle (50), and a printed circuit board stator (20). The printed circuit board (20) comprises two conductors printed on the same surface or on opposite surfaces of the printed circuit board. The two conductors produce alternating "square wave" patterns. The printed circuit board circuitry causes the direction of the current flow to reverse at intervals. The rotor rotates in response to the current flow in the stator. The rotation rate can be accurately controlled. The torque and average current consumption can be controlled by "chopping" the current with high frequency modulation whose duty cycle is proportional to the torque and average current consumption which will prolong the battery life of the motor.

PRINTED CIRCUIT BOARD MOTOR AND CONTROL SCHEME

The present invention generally relates to an electric motor incorporating
5 permanent magnets and, in particular, to a motor having a rotor with a series of
permanent magnets and a stator configured as a printed circuit board.

Electric motors of the type that include permanent magnets have become
ubiquitous and part of everyday life. Such motors have many uses, including
rotating small or light-weight parts of equipment in a precisely controlled manner.

10 The basic electric design of this type of motor has not changed significantly over
the years. Characteristically, current is switched to a series of conductor coils to
produce a rotating field. The magnets in the motor are then acted upon by the
rotating field, producing rotation of the rotor. Permanent magnet motors typically
use batteries which have a limited life to produce the electric current needed to
15 power the conductors.

It is desirable to incorporate an inexpensive electromagnetic motor in a
number of applications. A significant part of the cost of such motors reside in their
wire coils. It is also beneficial to have a two phase brushless system because it
consumes half the energy of a typical two-phase permanent magnet motor,
20 thereby, preserving and prolonging battery life. Finally, it is beneficial to have a
permanent magnet motor which can be controlled very accurately.

Also, there is the need for a motor whose speed is independent of the level
of current or voltage applied to the motor. It is also beneficial to have a
permanent magnet motor that allows variable torque and motor current so that

-2-

during speed changes extra torque and current can be applied but during constant, steady rotation, the current consumption is reduced.

In accordance with one embodiment of the present invention, a printed circuit board motor is disclosed. The motor comprises a rotor that comprises a
5 generally circular plate embedded with magnets that extend to the outer edge of the front surface of the rotor plate; an axle coupled to the back surface of the rotor plate; and a stator imprinted with a printed circuit board on its front surface that positioned adjacent and parallel to the front surface of the rotor plate. The printed circuit board comprises two conductors printed on the same surface or on
10 opposite surfaces of the printed circuit board. The conductors are oriented 90° out of phase with each other. The two conductors produce alternating "square wave" patterns. The printed circuit board circuitry causes the direction of the current flow to reverse at prescribed intervals. The magnets embedded in the rotor plate provide a magnetic field that passes through the printed circuit board. The
15 magnets around the edge of the rotor plate alternate north and south poles. The rotor rotates in response to the current flow in the stator. This rotation rate can be accurately controlled. The torque and average current consumption can be controlled by "chopping" the input current with relatively high frequency modulation whose duty cycle is proportional to the torque and average current
20 consumption.

Accordingly, it is an object of the present invention to provide an inexpensive rotating electric motor that provides accurate control of rotation rate and allows for variable torque and motor current so that during speed changes

-3-

extra torque and current can be applied, but during steady rotation, current consumption can be reduced, thereby, prolonging battery life.

It is also an object to increase battery life by reducing motor current to the amount needed to maintain the desired rotation rate, prolonging the battery life of the motor.

Other objects of the present invention will be apparent in light of the description of the invention embodied herein.

The following detailed description of specific embodiments of the present invention can be best understood when read in conjunction with the following drawings:

Fig. 1A is a side view of the printed circuit board motor according to an embodiment of the present invention;

Fig. 1B is an overhead view of the printed circuit board motor according to an embodiment of the present invention;

Fig. 1C is a forward view of the printed circuit board motor according to an embodiment of the present invention;

Fig. 1D is a view of the front surface of the rotor illustrating the location of the embedded magnets according to an embodiment of the present invention;

Figs. 2A and 2B illustrate the front and the back surfaces of the printed circuit board of the stator according to an embodiment of the present invention, without the printed windings;

Fig. 3 illustrates one conductor on the front surface of the printed circuit board of the stator according to an embodiment of the present invention;

-4-

Fig. 4 illustrates a second conductor on the back surface of the printed circuit board of the stator according to an embodiment of the present invention;

Figs. 5A and 5B illustrate both conductors on the front and the back surfaces of the printed circuit board of the stator according to an embodiment of the present invention;

Fig. 6 illustrates the circuit diagram for the printed circuit board stator according to an embodiment of the present invention;

Fig. 7 is a diagram of the different inputs and outputs of the printed circuit board diagram of Fig. 6 according to an embodiment of the present invention.

In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration, and not by way of limitation, a specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention.

Figs 1A-D diagrammatically illustrate a printed circuit board motor 10 from several different viewpoints. A rotor 30 of the printed circuit board motor 10 comprises a plate 31 having a front surface 32 and a back surface 33. The rotor 30 has a plurality of magnets 40 mounted on and extended to the outer edge of the front surface 32 of the rotor plate 31 as seen in Fig. 1D. The magnets 40 may also be embedded into the front surface 32 of the rotor plate 31. The plurality of magnets 40 on the rotor 30 alternate their north and south poles. That is,

-5-

proceeding around the periphery of the rotor 30, one encounters magnets with their north poles facing away from the rotor 30 interleaved with magnets with their south poles facing away from the rotor 30. The rotor plate 31 may be configured as a circular disc but other geometric shapes are possible. The rotor 30 is
5 attached to an axle 50. The axle 50 rotates with the rotor 30, and may be attached to whatever apparatus is to be driven by the motor 10. The axle 50 may be journaled in an appropriated bearing which is supported by a support arm 52.

The stator 20 comprises a printed circuit board 21 having a front surface 22 and a back surface 23. In one embodiment, the printed circuit board 21 of the
10 stator 20 can be part of a larger printed circuit board that controls the entire product and contains all the electronics for the product. In another embodiment, the printed circuit board 21 of the stator 20 controls only the printed circuit board motor 10. The front surface of the stator 20 is positioned across from, and parallel to, the front surface of the rotor 30. The plurality of magnets 40 on the rotor 30
15 extend from the rotor plate 31 at a distance that allows the magnetic fields produced by the magnets 40 to pass through the printed circuit board of the stator 20 and to prevent crosstalk. The rotor 30 and stator 20 do not touch.

The front surface 22 of the printed circuit board 21 of the stator 20 is illustrated in Fig. 2A. A processor U1 can be mounted on the front surface 22 of
20 the printed circuit board 21. Hall effect transducers U2 and U3 are also mounted on the front surface 22 of the printed circuit board 21. The back surface 23 of the printed circuit board 21 is illustrated in Fig. 2B.

-6-

The printed circuit board can be made of any number of layers and made by any of the well know methods of the art. In one embodiment, a first layer of the conductor is printed on front surface 22 of the printed circuit board 21 and is illustrated in Fig. 3. This first layer of conductor can be printed in a conductive

5 metal such as, for example, copper. A second layer of the conductor is printed on the back surface 23 of the printed circuit board 21 and is illustrated in Fig. 4. This second layer comprises the internal signal lines for the printed circuit board 21.

Figs 5A-B illustrate the conductors with both positive and negative components of the two conductors as they are printed on the front surface 22 and the back

10 surface 23 of the printed circuit board 21. Fig. 5A represents the conductor printed on the front surface 22 of the printed circuit board 21. Fig. 5B represents the conductor on the back surface 23 of the printed circuit board 21. The two front and back conductors are 90 degrees out of phase with each other and represent sinking and sourcing pairs. In another embodiment, the two front and back
15 conductors can be printed on a single surface of the printed circuit board 21 and can be connected by jumpers.

The two conductors produce alternating "square wave" patterns that are arranged in a circle. The processor U1 causes the direction of the current flow through the conductors to reversal at intervals resulting in the rotor 30 spinning.

20 The processor U1 controls the current flow with high frequency modulation. In addition, the torque and average current consumption of the printed circuit board motor 10 can be controlled by the processor U1. The processor U1 controls the current by "chopping" it with relatively high frequency modulation. This relatively

-7-

high frequency modulation has a duty cycle that is proportional to the torque and average current consumption. The rotor 30 rotates in response to the current flow in the printed circuit board 21. This rotation rate can be accurately controlled by the processor U1. Due to the method of alternating phases of the two conductors, speed is independent of current or voltage applied to the motor. Speed, torque and power consumption are, also, independently controlled.

Fig. 6 illustrates the circuit diagram for the printed circuit board stator according to an embodiment of the present invention. The printed circuit board 21 has any number of surfaces. The stator A and B represent the two conductors that are 90° out of phase with each other and that are printed on all of the surfaces of the printed circuit board 21. The two Hall effect transducers U2 and U3 and the processor U1 are also illustrated. The maximum gate to source voltage is +/- 12 volts for a bridge field effect transistor (FET) or +/- 3.5 volts for a 2N7002 printed circuit board

Fig. 7 is a diagram of the different inputs and outputs of the circuit diagram of Fig. 6 according to an embodiment of the present invention. Q1 represents the battery voltage input produced by the processor U1. As illustrated, the input is a chopped wave input that has a frequency that is relatively high compared to the switching frequency required for the desired rotation rate of the printed circuit board motor 10. The frequency can be, for example, about eight kilohertz, resulting in a period, for example, of about 125 microseconds. Q21 and Q22 represent the alternating positive and negative outputs from the conductor printed on the front surface 22 of the printed circuit board 21 of the stator 20. Q21

-8-

designates the positive output and Q22 the negative output. Q23 and Q24 represent the alternating positive and negative outputs from the conductor printed on the back surface 23 of the printed circuit board 21 of the stator 20 that are 90 degrees out of phase with the positive and negative outputs from the conductor printed on the front surface of the printed circuit board of the stator 20. Q23 designates the positive output and Q24 the negative output. In addition, Q24 lags behind Q22 by a function of the desired rotation speed based on the speeds and geometry of the conductor patterns on the printed circuit board 21. The lag, for example, can be approximately 100 milliseconds. Q21, Q22, Q23 and Q24 represent the modulation effect of the chopped input current of Q1.

Because a chopped input wave is used, less electrical energy is needed to spin the rotor 30. Even though there is an increased need for current to start the printed circuit board motor 10 or to change the speed, the current consumption decreases once the rotor 30 is spinning at a constant steady speed, thereby lowering overall energy costs. Through the use of the chopped wave, half the effective electrical energy is used, thereby prolonging the battery life by twofold over the average printed circuit board motor life resulting in greater cost savings.

It is noted that terms like "preferably," "commonly," and "typically" are not utilized herein to limit the scope of the claimed invention or to imply that certain features are critical, essential, or even important to the structure or function of the claimed invention. Rather, these terms are merely intended to highlight alternative or additional features that may or may not be utilized in a particular embodiment of the present invention.

-9-

Having described the invention in detail and by reference to specific embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention defined in the appended claims. More specifically, although some aspects of the present
5 invention are identified herein as preferred or particularly advantageous, it is contemplated that the present invention is not necessarily limited to these preferred aspects of the invention.

-10-

CLAIMS

1. A printed circuit board motor, comprising:

a rotor comprising

5 a plate having a front and back surface, and

a plurality of magnets mounted adjacent to the outer edge of said

plate rotor on said front surface thereof;

an axle coupled to said back surface of said plate in the center of said

plate; and

10 a stator having a front surface and a back surface and said front surface

being positioned adjacent and parallel to said front surface of said

plate, said stator including:

a printed circuit board having at least two conductors; and

a processor for controlling application of power to said conductors.

15 2. The printed circuit board motor of claim 1, wherein said plate of said rotor is circular.

3. The printed circuit board motor of claim 1, wherein said printed circuit board of said stator further includes a plurality of Hall effect transducers.

4. The printed circuit board motor of claim 1, wherein said plurality of magnets

20 are arranged adjacent the edge of said plate of said rotor such that magnets

having outward facing north poles alternate with magnets having outward facing

south poles around the edge of said plate.

-11-

5. The printed circuit board motor of claim 1, wherein each of said plurality of magnets protrudes a distance from the edge of said front surface of said plate of said rotor.

5 6. The printed circuit board motor of claim 1, wherein each of said plurality of magnets provides a magnetic field that passes through said printed circuit board of said stator.

7. The printed circuit board motor of claim 1, wherein said plurality of magnets are positioned relative to the edge of said front surface of said plate of said rotor
10 such that field effect crosstalk is prevented.

8. The printed circuit board motor of claim 1, wherein said printed circuit board has a front surface and a back surface and wherein said at least two conductors are printed on opposite surfaces of said printed circuit board, wherein one of said at least two conductors is printed on said front surface of said stator and the other
15 of said at least two conductor is printed on said back surface of said stator.

9. The printed circuit board motor of claim 1, wherein said at least two conductors are printed on said single surface of said printed circuit board, wherein said at least two conductors connected by jumper connections.

10. The printed circuit board motor of claim 1, wherein said at least two
20 conductors are orientated 90° out of phase with each other around the periphery of said stator.

-12-

11. The printed circuit board motor of claim 1, wherein the current provided to one of said at least two conductors lags the current provided to the other of said at least two conductors.

5 12. The printed circuit board motor of claim 11, wherein said lag between said at least two conductors is a function of the desired rotation speed.

13. The printed circuit board motor of claim 1, wherein current is supplied to said two conductors as alternating square wave patterns.

14. The printed circuit board motor of claim 13, wherein the speed of rotation of
10 said rotor is independent of the levels of current and voltage applied to said printed circuit board motor.

15. The printed circuit board motor of claim 1, wherein said processor causes direction of current flow through said conductors to reverse at intervals, resulting in rotation of said rotor.

15 16. The printed circuit board motor of claim 1, wherein said processor controls current flow through said conductors through the use of frequency modulation.

17. The printed circuit board motor of claim 16, wherein said frequency modulation has a duty cycle that is proportional to torque and average current consumption.

20 18. The printed circuit board motor of claim 17, wherein said torque and average current consumption is controlled by chopping the current at a relatively high frequency.

19. The printed circuit board motor of claim 18, wherein said current

-13-

consumption decreases once said rotor is rotating at a constant speed.

20. The printed circuit board motor of claim 18, wherein said chopped current has a frequency that is relatively high compared to the switching frequency required for the desired rotation rate.

1 / 10

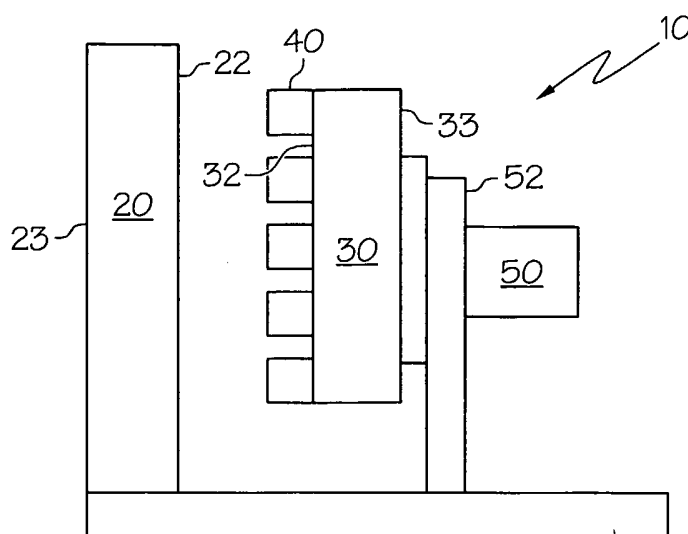


FIG. 1A

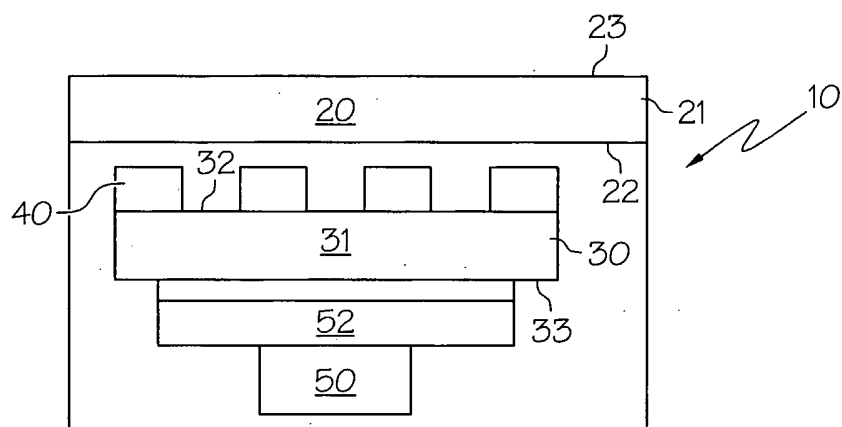


FIG. 1B

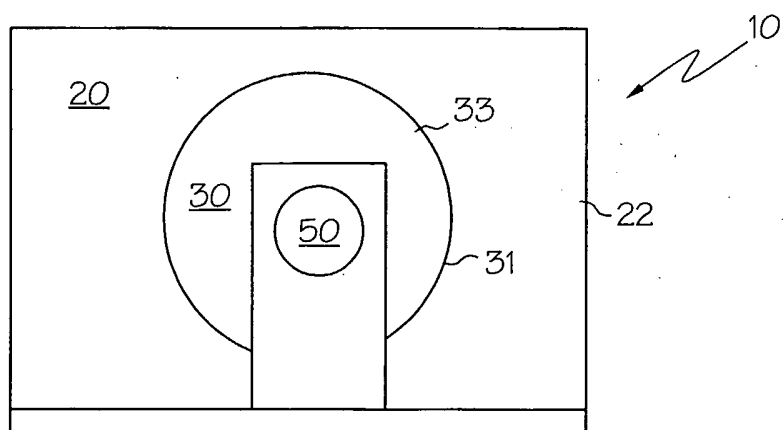


FIG. 1C

2 / 10

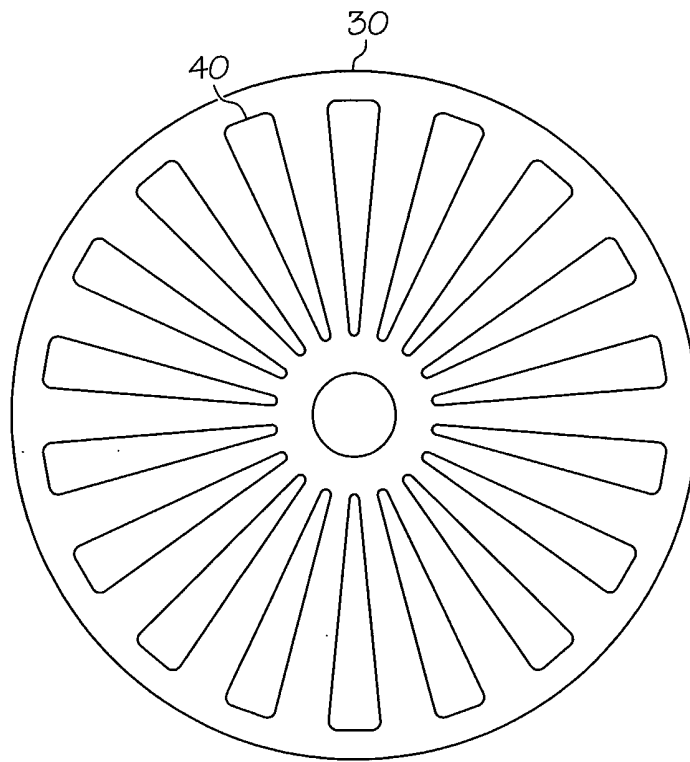


FIG. 1D

3 / 10

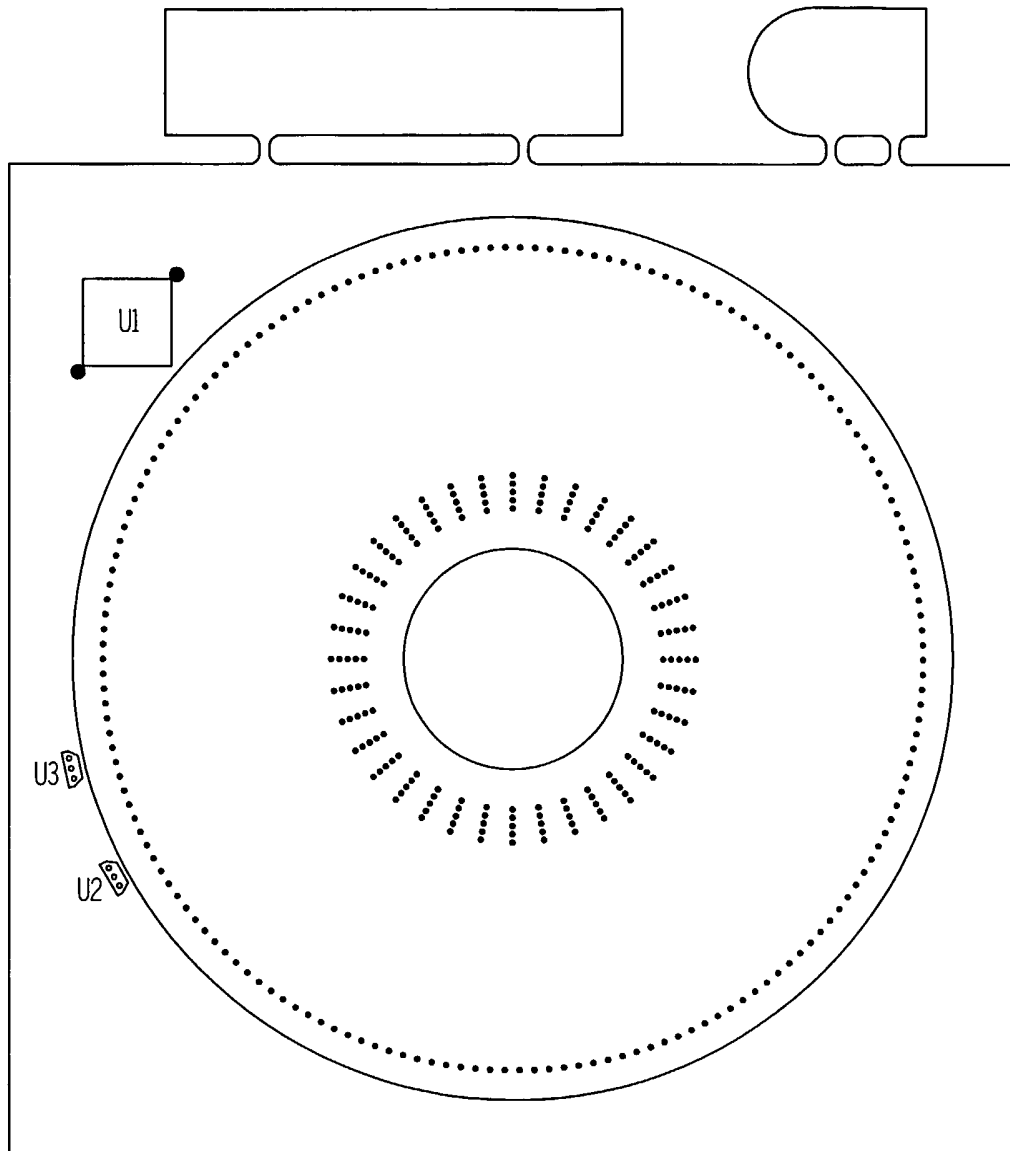


FIG. 2A

4 / 10

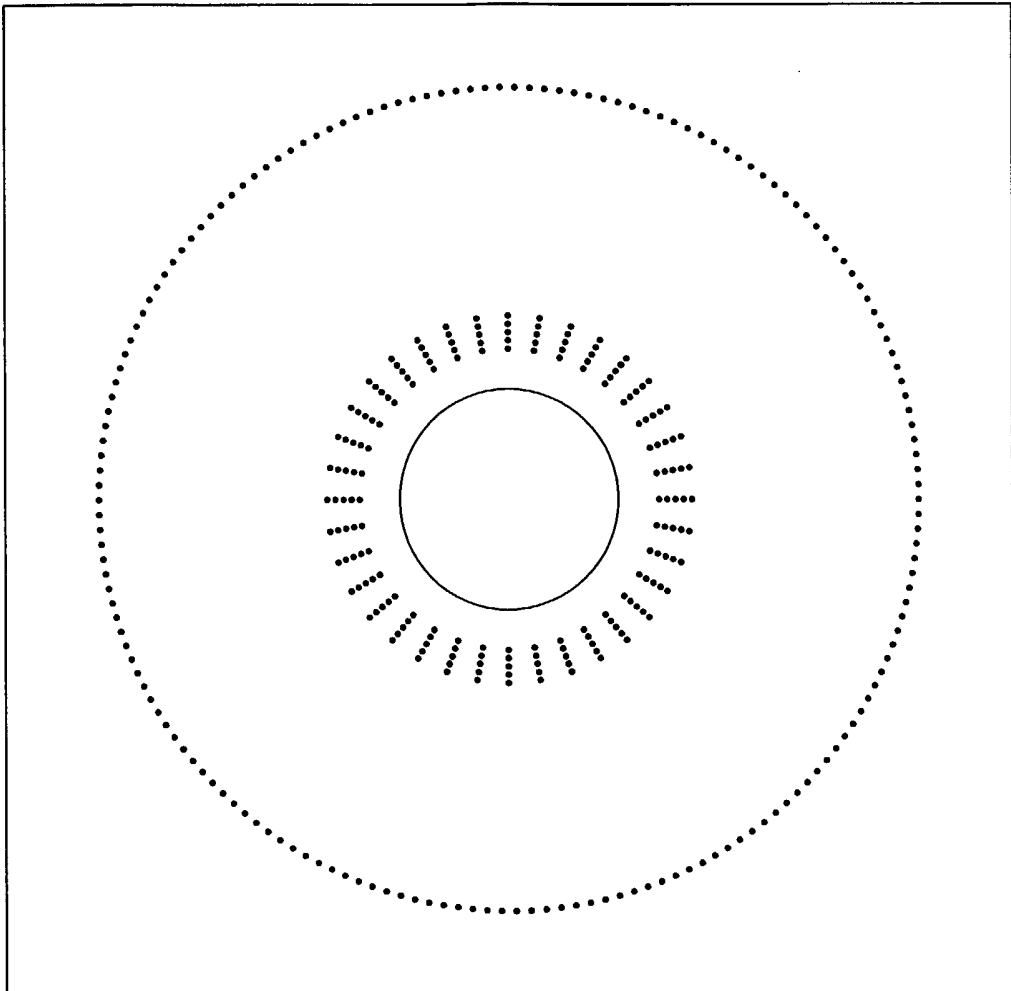


FIG. 2B

5 / 10

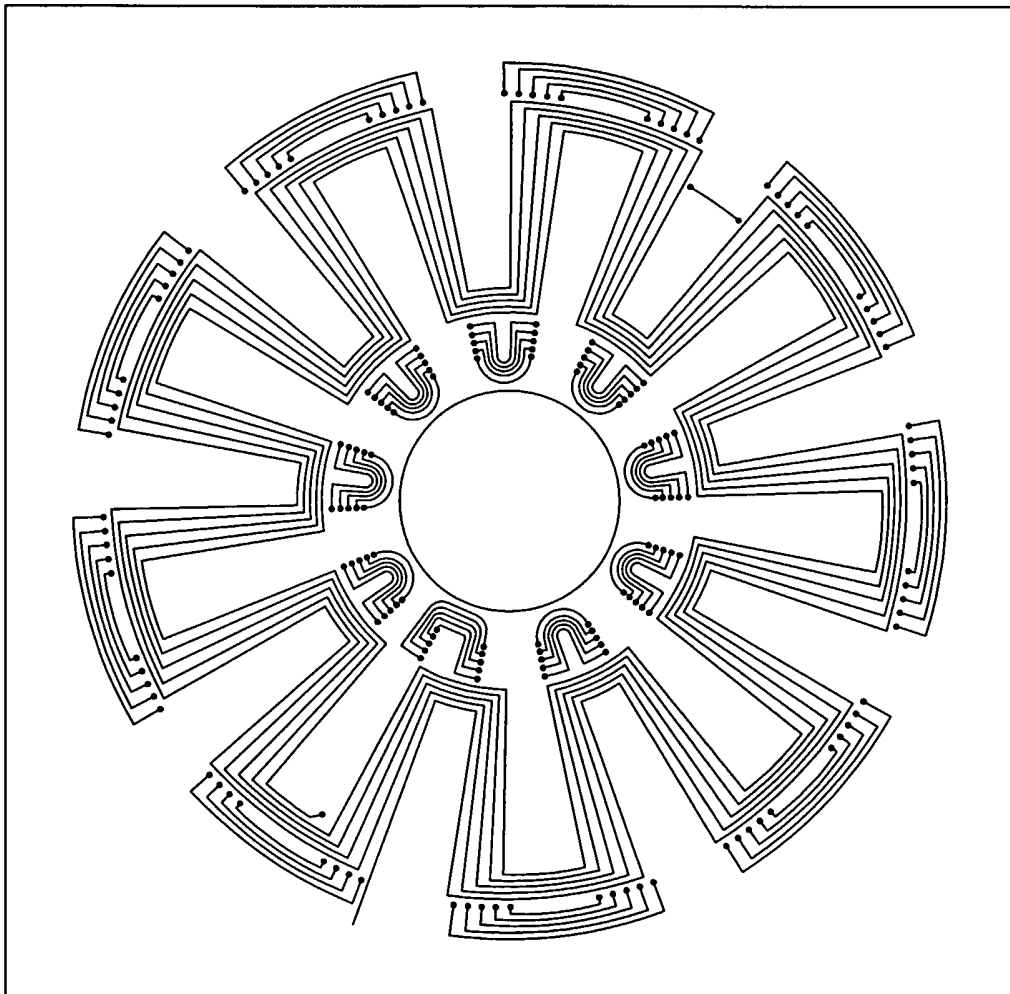


FIG. 3

6 / 10

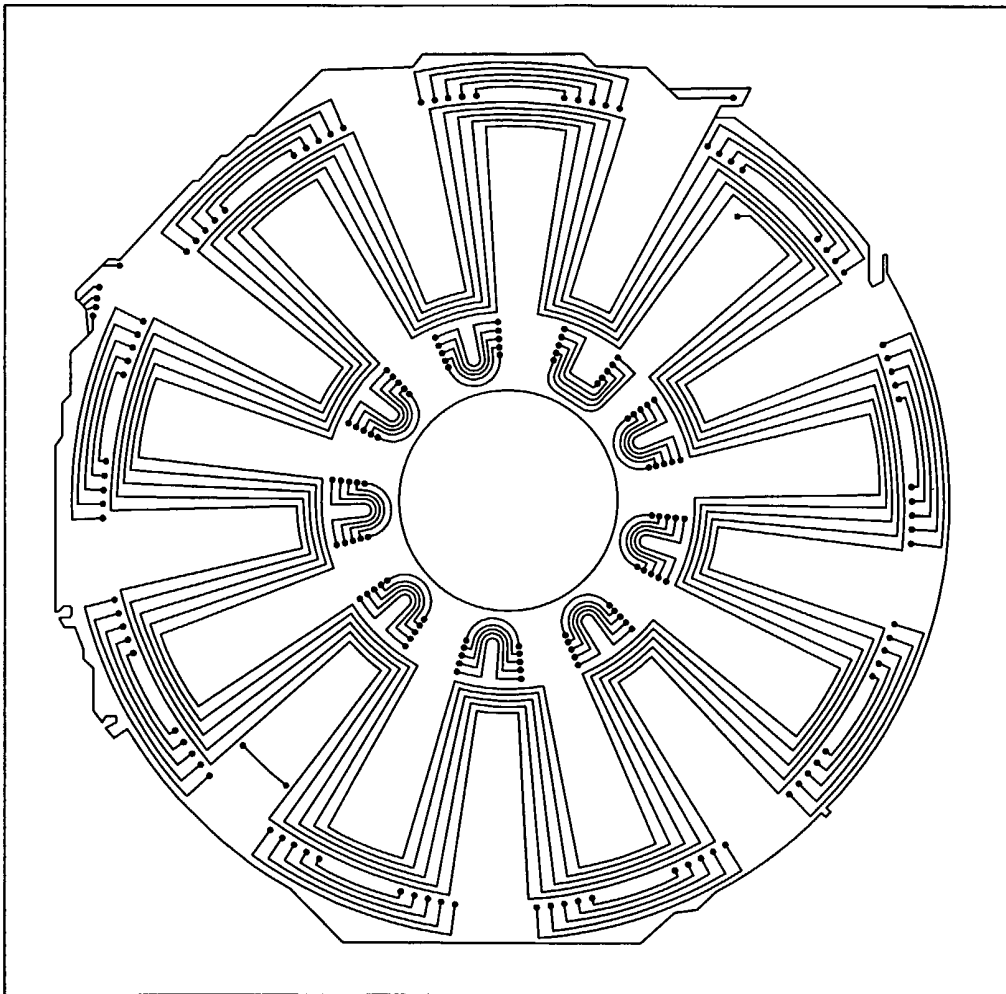


FIG. 4

7 / 10

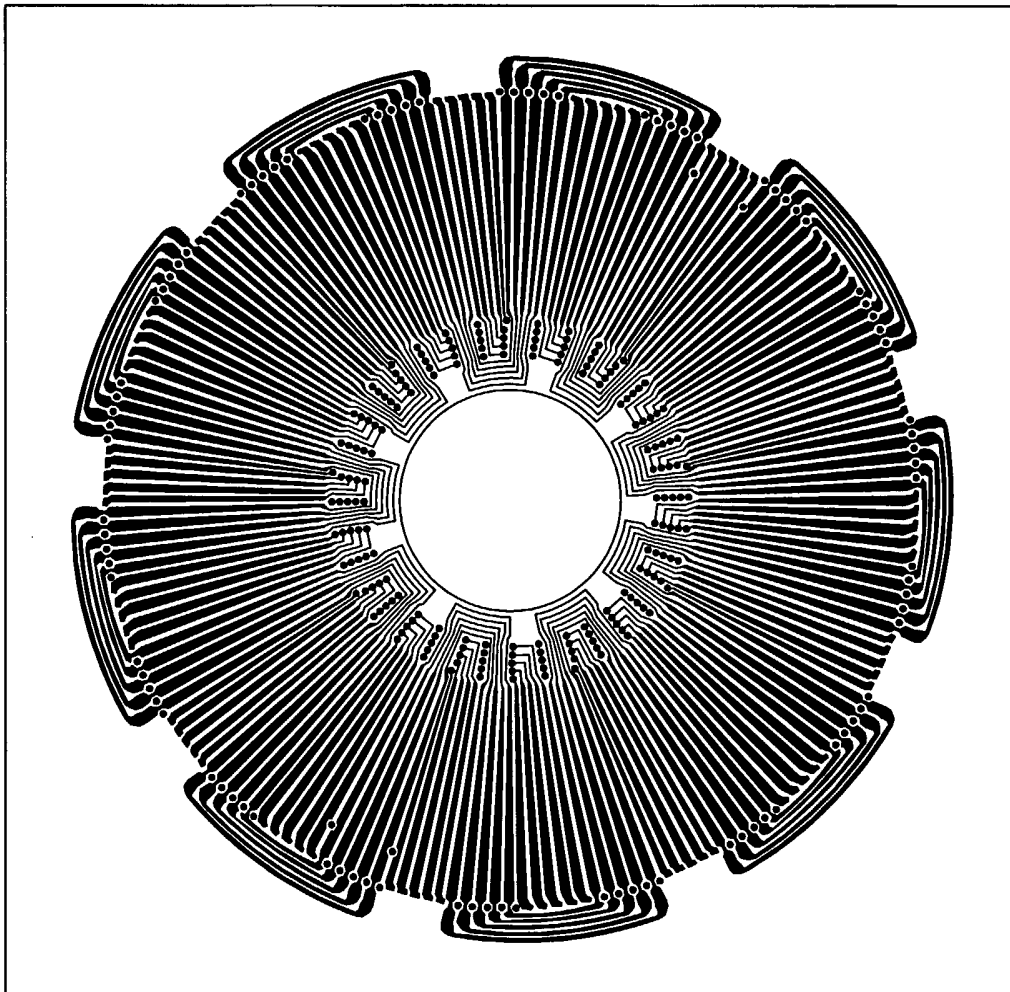


FIG. 5A

8 / 10

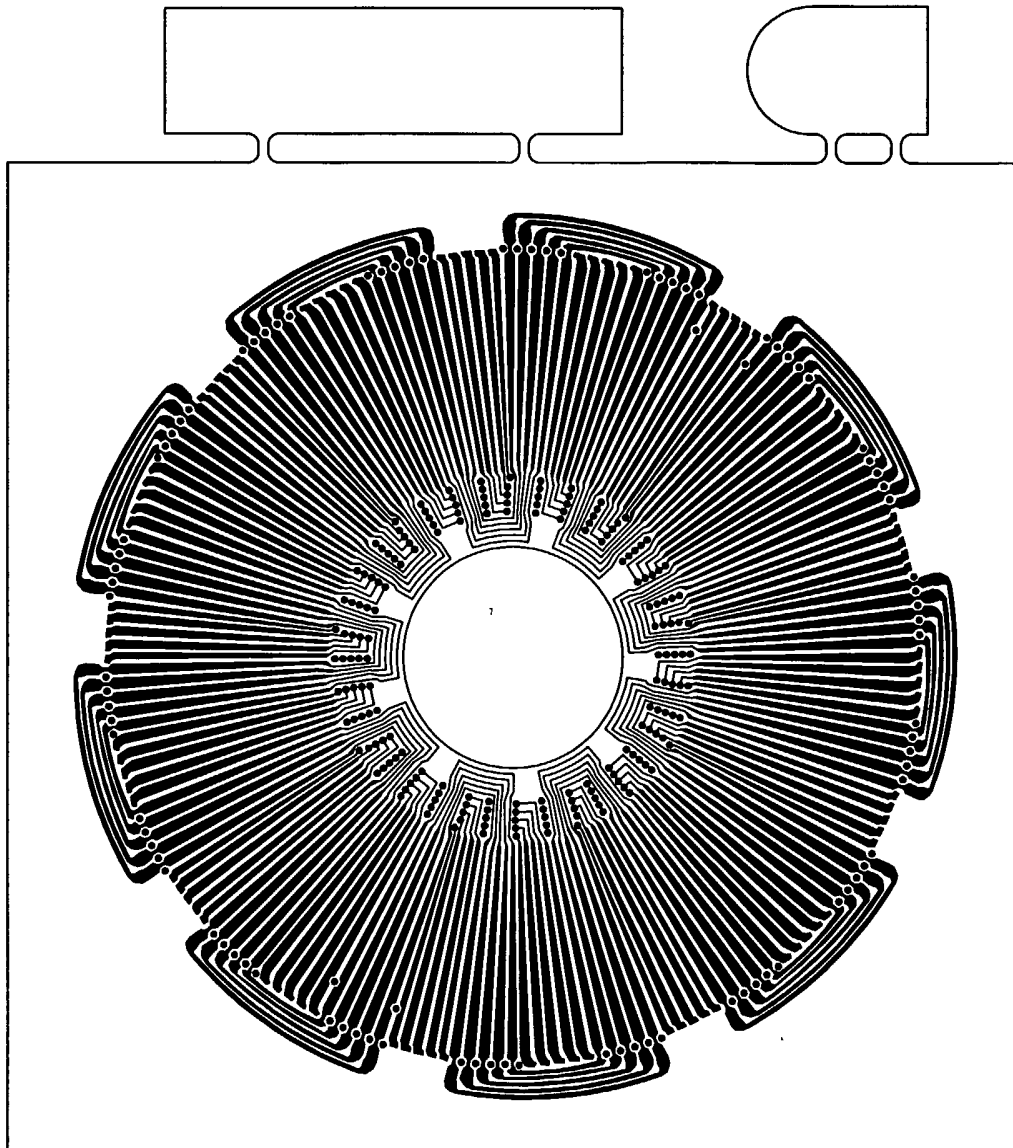
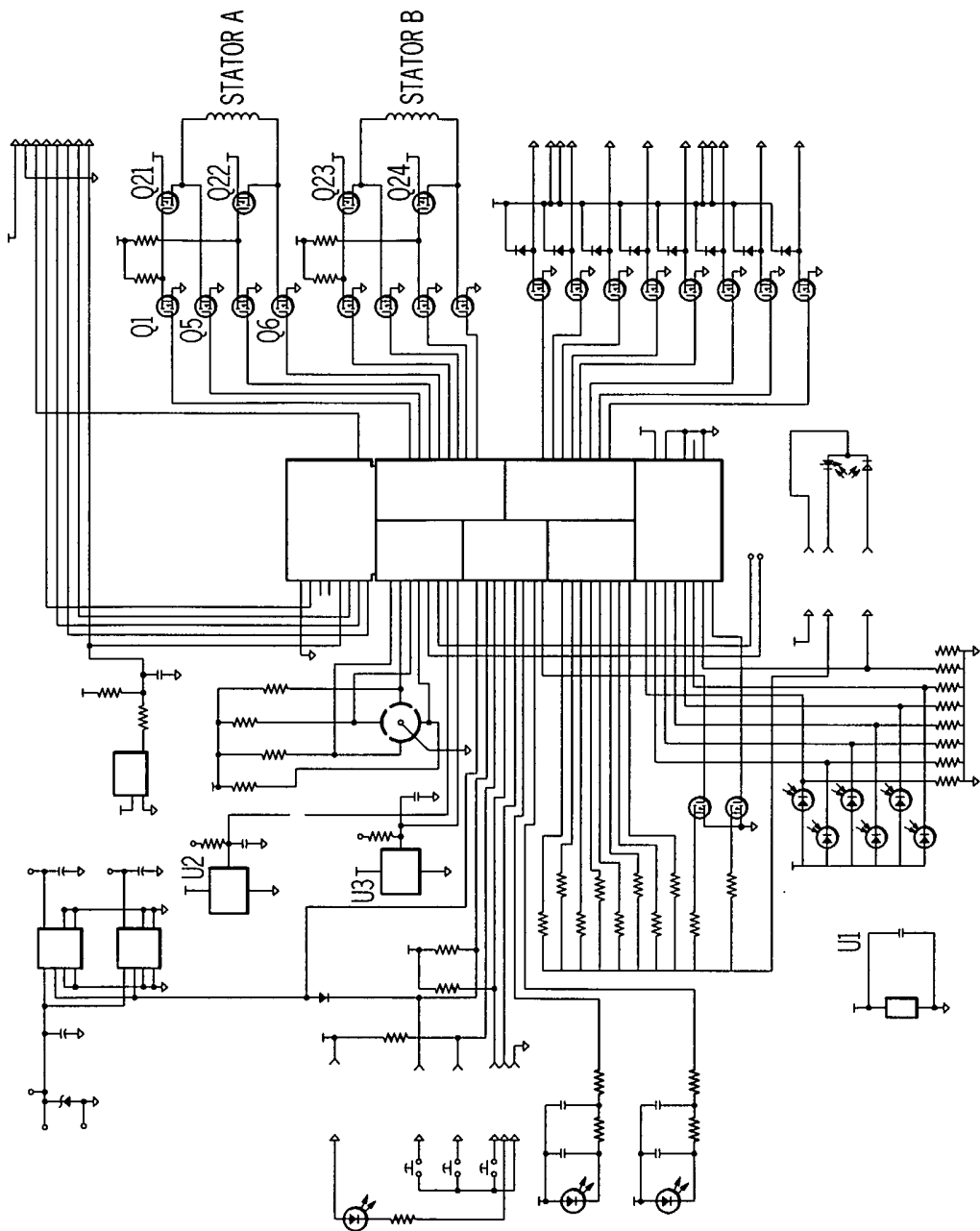


FIG. 5B

9 / 10



66.6

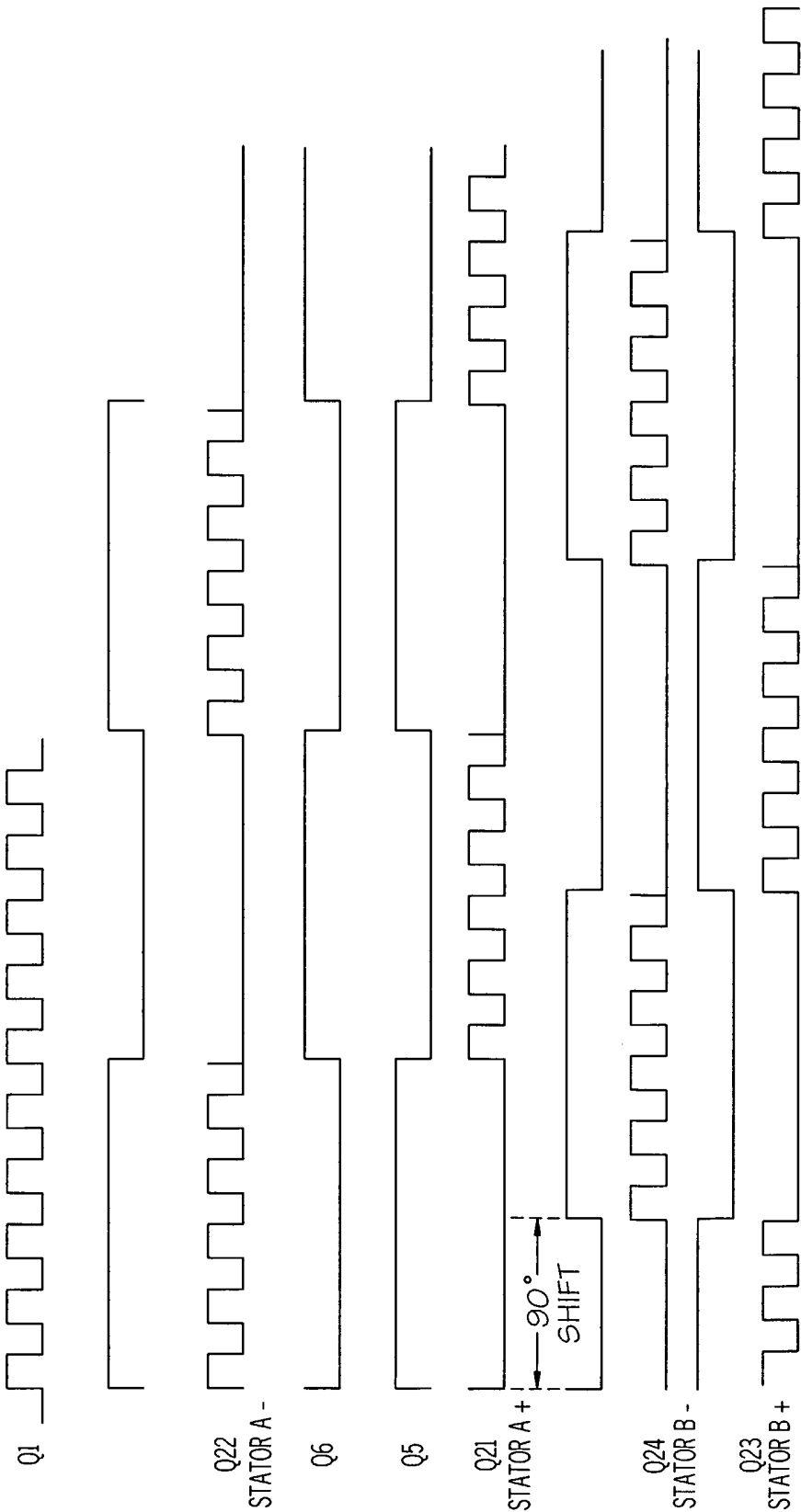


FIG. 7

INTERNATIONAL SEARCH REPORT

Intern I Application No
PCT/US2005/011583

A. CLASSIFICATION OF SUBJECT MATTER
H02K21/24 H02K3/26 H02K29/08 H02P6/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H02K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EP0-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 005 324 A (KIM ET AL) 21 December 1999 (1999-12-21) abstract; figures 2-4 column 2, line 25 - line 40 column 2, line 60 - line 63 -----	1,2,4-7, 9
X	US 5 589 722 A (SAKAGUCHI ET AL) 31 December 1996 (1996-12-31) abstract; figures 1-7,14,18,21-25 sentence 21 - sentence 55 column 3, line 27 - line 51 -----	1-7 11-20
Y		
X	WO 2004/064087 A (HOTINSKI, VLADIMIR; BEALE, DAVID, GEORGE) 29 July 2004 (2004-07-29) page 6, line 24 - page 7, line 4 page 28, line 3 - line 4; figures 1-16 ----- -/--	1-4,6,7

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

1 December 2005

Date of mailing of the international search report

17 FEB 2006

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Segaert, P

INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/US2005/011583

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2004/073365 A (CORE INNOVATION, LLC; JORE, MATTHEW, B; JORE, LINCOLN, M) 26 August 2004 (2004-08-26) page 9 page 11, line 22 - page 13, line 4; figures 13a,13b,13c -----	1-4,6-8
X	US 6 411 002 B1 (SMITH STEPHEN H ET AL) 25 June 2002 (2002-06-25) column 6, line 31 - line 55 column 7, line 35 - column 8, line 18 -----	1,4,6-8, 10
Y	WO 99/48187 A (LIGHT ENGINEERING CORPORATION) 23 September 1999 (1999-09-23) page 28, line 5 - line 13; figure 5 -----	11-20
A	US 6 005 320 A (KIM ET AL) 21 December 1999 (1999-12-21) -----	11-20
A	US 4 228 384 A (ARNOLD, JR. ET AL) 14 October 1980 (1980-10-14) -----	11-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2005/011583

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 6005324	A	21-12-1999	GB 2327304 A JP 11075354 A	20-01-1999 16-03-1999
US 5589722	A	31-12-1996	NONE	
WO 2004064087	A	29-07-2004	NONE	
WO 2004073365	A	26-08-2004	AU 2004211408 A1 CA 2514772 A1 EP 1590871 A2	26-08-2004 26-08-2004 02-11-2005
US 6411002	B1	25-06-2002	AU 7851098 A EP 1016198 A2 JP 2001510677 T WO 9826495 A2 US 6181048 B1 US 6163097 A US 5982074 A	03-07-1998 05-07-2000 31-07-2001 18-06-1998 30-01-2001 19-12-2000 09-11-1999
WO 9948187	A	23-09-1999	AT 281019 T AU 6567998 A CA 2323641 A1 DE 69827299 D1 DE 69827299 T2 EP 1062718 A1 JP 2002507878 T	15-11-2004 11-10-1999 23-09-1999 02-12-2004 01-12-2005 27-12-2000 12-03-2002
US 6005320	A	21-12-1999	NONE	
US 4228384	A	14-10-1980	AU 4569579 A CH 652257 A5 DE 2918493 A1 FR 2425755 A1 GB 2020915 A GB 2110123 A IE 48332 B1 IT 1163996 B JP 1921898 C JP 6028499 B JP 54147404 A NL 7903619 A	15-11-1979 31-10-1985 22-11-1979 07-12-1979 21-11-1979 15-06-1983 12-12-1984 08-04-1987 07-04-1995 13-04-1994 17-11-1979 12-11-1979

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2005/011583

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-10

printed circuit motor

2. claims: 11-20

control scheme for brushless electric motor
