

DescriptionCross-Reference to Related Application

- 5 This invention is useful, for example, in the motor disclosed in U.S. Application Serial No. 116,374 filed November 2, 1987, by E. Klein, entitled SINGLE HOUSING STEPPER MOTOR.

Field of the Invention

- 10 This application is directed to stepper motors for use in disc drives, and more particularly to a method and apparatus for compensating for motor resistance changes due to temperature variations.

Background of the Invention

- 15 In the typical disc drives using a stepper motor, one must develop an algorithm for controlling the stepper motor to move the head from one track to another selected track that may be 100 or more tracks away. In the process of doing this, the motor is accelerated to very high speeds and then rapidly decelerated and stopped. This rapid acceleration and deceleration is implemented in part by putting the time between each step pulse in a lookup table accessible by the motor controlling microprocessor. These
20 time periods are critical to the drive performance. A 1 microsecond shift in those time periods can throw the time periods off, so that the settling of the head relative to the tracks on the disc drive is no longer optimum.

- Since the stepper motor in a hard disc drive will be exposed to a specific broad, prespecified thermal range (4°C to 70°C), the winding resistance of the stepper motor will change due to the varying
25 temperature. This change is predictable and repeatable. Typically, the motor resistance (R_m) will change about 1.393%/°C. An equation for the motor resistance at any temperature can be expressed as the following:

$$R_m = R_o + R_o T_{cm} (T - T_o) \quad (1)$$

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where

- R_o = Nominal resistance at ambient room temperature
 T_{cm} = Thermal resistive coefficient (.393%/°C for copper)
 T_o = Ambient room temperature of 25°C
 35 T = operating temperature

It is detrimental to motor performance to have this increase in resistance at higher temperatures, since it reduces motor torque (from that at lower temperatures) and alters the L/R time constant of the system. The alteration of the L/R time constant is particularly harmful because the motor step algorithm that incorporates the lookup table described above cannot be retuned to account for this change in the electrical system.

- 40 The alteration of the current will result in a torque change in the motor. This change in torque can be minimized in part by tuning the motor voltage as is done by most disc drive manufacturers; but to a certain extent, the proper tuning of the motor is overcome by this change in current, since the change in motor voltage accomplished by tuning can partially change the current to compensate for the resistance changes, but the correction cannot be as complete and accurate as desired. That is, the L/R time constant will not
45 change as the voltage applied to the phase is changed, and therefore, tuning by modification of the applied voltage will not accurately compensate for this alteration in the system. Thus, the potential alteration of the L/R time constant with changes in temperature must be accounted for in some other way in order to maintain the high degree of accuracy required in a disc drive.

- Prior patent specifications GB215335 and DE725666 both feature windings composed of materials with
50 differing temperature coefficients in order to compensate for temperature changes.

It is an objection of this invention to provide a motor for use in a disc drive whose performance is made more reliable and is better insulated from variations in the motor torque induced by changes in the operating environment temperature.

- More particularly, it is an objective herein to provide a method for compensating for a change in motor
55 coil resistance due to varying temperature during a disc drive's period of operation by the use of negative temperature coefficient thermistors.

A related objective is to incorporate negative temperature coefficient thermistors in a disc drive motor to avoid variations in the L/R time constant, and thereby motor torque variations with changing operating

temperatures.

The invention provides a stepper motor for a disc drive comprising a housing, a rotating shaft mounted in said housing for carrying a rotor, a plurality of stator coils mounted in parallel on the inner surface of said housing, a printed circuit board supported by said housing adjacent exposed ends of said coils, and a microprocessor for supplying controlling step pulses to said motor at periodic intervals established in an open-loop look-up table in a memory associated with said microprocessor, and at least one thermistor mounted on said printed circuit board adjacent said coils and connected to at least one of said coils and responsive to temperature changes in said coils to maintain total motor resistance at a constant level over a range of operating temperatures of said motor, whereby the controlling step pulses applied by said microprocessor accurately position said stepper motor over a wide range of temperatures.

In another embodiment of the invention there is provided a disc drive, comprising a stepper motor having a housing, a rotating shaft mounted in said housing for carrying a rotor, a plurality of stator coils mounted within said housing, control wires leading to said coils for selective energization thereof for causing rotation of said rotor, and a microprocessor for supplying controlling step pulses to said motor at periodic intervals established in an open-loop look-up table in a memory associated with said microprocessor, said drive further comprising a printed circuit board supporting thermistors connected in series with said coils and responsive to temperature changes in said disc drive to maintain total motor resistance at a constant level over a range of operating temperatures of said motor, whereby the controlling step pulses applied by said microprocessor accurately position said stepper motor over a wide range of temperatures.

Thus, with increases in temperature, the resistance of the negative temperature coefficient thermistor will decrease, lowering the resistance of the motor circuit and maintaining the L/R time constant of the system. The opposite effect will occur with decreasing temperature. Constant torque is thereby maintained over a range of temperatures.

To adjust for the fact that thermistors that accurately reflect the changes in resistance of the wire used to wind the coils with changes in temperature are not available, a resistor is wired in parallel with the thermistor, the resistor having a value chosen to modify the total resistance represented by the thermistor network to the coils so that the compensation is accurate over a wide range of changes in temperature and motor design. The shunt resistor allows flexibility in motor design, as it can have any selected value from zero to infinity to compensate for variations in motor design. If such flexibility is not necessary, the thermistor and resistor could be incorporated in a single package.

The features and advantages of this invention will be better understood from reference to the following drawings, wherein

FIG 1 is an exploded view of a stepper motor incorporating the present invention;

FIG 2 is a bottom plan view of the motor of FIG 1 with the PCB removed showing the arrangement of the stator coils and the rotor;

FIG 3 is a schematic of the thermistor circuit of the invention;

FIG 4A illustrates one side of the printed circuit board that fits over the bottom of the coils that appear in FIG 2 and supports the shunt resistors and thermistor circuits of this invention;

FIG 4B illustrates in plan view the other side of the printed circuit board that supports the thermistor circuits of this invention.

FIG 5 illustrates resistance of the motor coil wire both compensated and uncompensated with changes in temperature;

FIG 6 illustrates the effect of the thermistor compensation network in modifying the resistance with temperature;

FIGs 7A-7D illustrate the effect on access time of incorporating this invention in an actual disc drive; and FIGs 8 and 9 illustrate an alternative embodiment showing the effects of incorporating this invention on a printed circuit board external to the motor tested under simulated operating conditions.

Detailed Description of a Preferred Embodiment

Referring first to FIG 1, the essential elements of the motor of the type that may incorporate this invention are shown. This motor is described solely for the sake of example, and the utility of this invention is not limited to this particular motor design. Details of the motor design that appear in FIG 1 may be found in the application of Enrique Klein referred to above.

The motor 1 includes a central shaft 2 supporting a rotor 3 for rotation with selective activation of the stator coils incorporated in the stator stack 4. The stator stack 4 is supported within the housing 5 to maintain its alignment with rotor 4. The top of the shaft 2 carries a pulley 6 having pins (for example) used to attach bands that are distally connected to a carriage mounting read/write transducers for select

positioning of the carriage with rotation of the shaft. The upper end of the shaft also carries, below pulley 6, a retaining ring 7, seal sleeve 8, magnetic seal 9, and ball bearing 10. The stator stack is insulated from the housing by insulator 11. Below the rotor 3, along shaft 2 can be found the bearing holder 12, disc spring 13 for maintaining the bearing holder in place, rear ball bearing 14 and retaining spring 15. The assembly is completed with rear cover 16, washer 17 and screw 18 which hold the assembled motor together.

As shown in greater detail in the bottom plan view of FIG 2, a plurality of actuator poles 26 are provided on which the coils 28 of the stator are wound. As discussed above, it is the change in resistance of the wires of the stator coils 28 with varying temperature within the motor housing that must be compensated for. If accurate compensation can be incorporated, the stepper motor coils act as an electrical load with an essentially constant resistance over the normal specified operating temperature range of the disc drive.

On a printed circuit board mounted immediately below the stator coils, a thermistor network 29 as shown in FIG 3 is provided in series with each coil or serially connected group of coils. The network consists of a thermistor 30 chosen to have a characteristic of decreasing electrical resistance with increasing temperature identified as R_{th} 30. To allow for differences in stator coil designs, a shunt resistor R_{sh} 32 is provided to modify the resistive characteristic of the thermistor compensation network to the desired value. The resistor 32 and thermistor 30 network is placed in series with the resistance of the motor coils R_m 34. In the illustrated embodiment of this invention, 10 coils are used in the motor; they are serially connected in pairs, with a thermistor compensation network 29 of the type shown in FIG 3 being connected in series with each coil pair.

The actual mounting of the network can be seen in FIGs 4A and 4B. FIG 4A shows a printed circuit board 36 of a type normally mounted in a stepper motor with the wire traces 50 that provide the connections to the stator coil wires. The board 36 has been modified to accommodate the resistors R_{sh} 32 not shown on FIG 4A which will be mounted on the side of the board away from the coils. The thermistors R_{th} 30 are mounted on the opposite side of the board as shown in FIG 4B. The thermistors 30 are located and spaced to be closely adjacent to and preferably protruding between the stator coils 28 so that the temperature of the thermistor R_{th} 30 accurately reflect the temperature of the coils.

The electrical schematic of the network is shown in FIG 3. From this schematic, equations can be written to describe the resistive behavior of a particular phase which comprises a pair of coils as follows:

$$R_{tot} = \frac{R_{sh} R_{th}}{R_{sh} + R_{th}} + R_m \quad (2)$$

where:

R_{th} = $f(\text{temp})$ = thermistor resistance
 R_m = $f(\text{temp})$ = motor winding resistance
 R_{sh} = fixed shunt resistor

Since both the motor and thermistor resistance (R_m and R_{th}) are a function of temperature, expressions can be written to describe the total network resistance as a function of temperature.

For the thermistors used in prototype testing, the recommended resistive equation can be written as shown.

$$\frac{R_{th}}{R_{25}} = e^{\beta \left(\frac{1}{T_k} - \frac{1}{T_{k0}} \right)} \quad (3)$$

where:

β = thermistor material constant
 R_{th} = resistance at absolute temperature T_k
 R_{25} = resistance at absolute temperature T_{k0} (given by manufacturer specifications)
 T_{k0} = $298.15^\circ \text{K} = 25^\circ \text{C}$

Equations 1 and 3 can be substituted into equation 2 to yield a final expression for the total resistance of a particular motor coil circuit as a function of temperature. The final expression can be simulated by a computer to graphically show the effect of the thermistor circuit presence.

The dashed line in FIG 5 shows an analytical plot of resistance versus temperature for a typical stepper motor incorporating a resistor in series with the motor coils. It also shows a plot (solid curve) of the total motor coil circuit resistance versus temperature including the thermistor temperature compensation network shown in FIG 3 with the following parameters used:

$$\begin{aligned} R_m &= 16.5\Omega \text{ (at } 21.8^\circ\text{C)} & R_{25} &= 50\Omega \text{ (at } 25^\circ\text{C)} \\ R_{sh} &= 11\Omega \text{ (fixed carbon)} & \beta &= 3000 \end{aligned}$$

Here it can be seen that the conventional motor resistance with 10Ω series resistor will deviate approximately 3.1Ω over the total temperature range (about 19% change overall) where the resistance of the thermistor network compensated motor coil circuit is almost perfectly constant.

Testing was performed to experimentally verify the computer simulation; the results can be found in FIG 6. Here, three different sets of curves can be seen. The line A represents the analytical simulation data, line B represents experimental testing with no current in the motor coil circuit, and finally, the line C represents the motor coil circuit energized with approximately 125 milliamps. Here, it can be seen that the curve C shifted downward by about $.5\Omega$ from the curve B when current was applied to the motor coil circuit. This is due to the inherent self-heating effect of the thermistor. When current is applied to a resistive load, power is dissipated in the form of heat (IR loss). This causes an increase in thermistor temperature which translates to a slight decrease in thermistor resistance.

Drive level testing was also performed and the results can be seen in FIGs 7A-7D. The curves in these figures represent the access times of the thermistor motor with and without the compensation of this invention.

FIGs 7A and 7C illustrate a single track average seek time and random average track seek time without the thermistor used according to this invention. FIG 7B and 7D illustrate the maintenance of low access times with changes in temperature if this invention is used.

From these tests, it can be concluded that the thermistor network will compensate for the resistance change due to temperature change of the motor windings. Alternatively, the thermistor compensation circuit can be located on a board external to the motor.

In order to be able to predict how the thermistor circuit will affect the overall resistance if it is mounted on an external board rather than in the motor, testing was done to show how the external board temperature deviates from the motor temperature. For this, tests were done in which the temperatures of the motor and the external board were monitored for a period of about 70 minutes. The experimental results from these tests can be seen in FIG 8.

From these tests, it can be seen that the drive board stays approximately 10°C hotter than the motor. This was entered into the computer simulation and a new optimum thermistor and shunt combination was found.

FIG 9 shows a plot of the total resistance (of both the thermistor network and motor coils) versus temperature for the external board mounted thermistor. It can be seen from this plot that with a 20Ω thermistor and a 12Ω shunt resistor, the circuit can be accurately compensated with the thermistor mounted on the drive board.

Claims

1. A stepper motor (1) for a disc drive comprising a housing (5), a rotating shaft (2) mounted in said housing (5) for carrying a rotor (3), a plurality of stator coils (28) mounted in parallel on the inner surface of said housing (5), a printed circuit board (36) supported by said housing (5) adjacent exposed ends of said coils (28), and a microprocessor for supplying controlling step pulses to said motor at periodic intervals established in an open-loop look-up table in a memory associated with said microprocessor, and at least one thermistor (30) mounted on said printed circuit board (36) adjacent said coils (28) and connected to at least one of said coils (28) and responsive to temperature changes in said coils (28) to maintain total motor resistance at a constant level over a range of operating temperatures of said motor (1), whereby the controlling step pulses applied by said microprocessor accurately position said stepper motor (1) over a wide range of temperatures.
2. A motor (1) for a disc drive as in Claim 1 wherein said motor coils (28) are connected in series pairs, a thermistor (29) connected in series with each of said pairs and mounted adjacent said coils (28) for sensing the temperature of said coils (28), the resistance of the thermistor (30) changing with temperature to modify the voltage to the coils.

The dashed line in FIG 5 shows an analytical plot of resistance versus temperature for a typical stepper motor incorporating a resistor in series with the motor coils. It also shows a plot (solid curve) of the total motor coil circuit resistance versus temperature including the thermistor temperature compensation network shown in FIG 3 with the following parameters used:

- 5 $R_m = 16.5\Omega$ (at 21.8°C) $R_{25} = 50\Omega$ (at 25°C)
 $R_{sh} = 11\Omega$ (fixed carbon) $\beta = 3000$

Here it can be seen that the conventional motor resistance with 10Ω series resistor will deviate approximately 3.1Ω over the total temperature range (about 19% change overall) where the resistance of the thermistor network compensated motor coil circuit is almost perfectly constant.

- 10 Testing was performed to experimentally verify the computer simulation; the results can be found in FIG 6. Here, three different sets of curves can be seen. The line A represents the analytical simulation data, line B represents experimental testing with no current in the motor coil circuit, and finally, the line C represents the motor coil circuit energized with approximately 125 milliamps. Here, it can be seen that the curve C shifted downward by about $.5\Omega$ from the curve B when current was applied to the motor coil circuit. This is
 15 due to the inherent self-heating effect of the thermistor. When current is applied to a resistive load, power is dissipated in the form of heat (IR loss). This causes an increase in thermistor temperature which translates to a slight decrease in thermistor resistance.

- Drive level testing was also performed and the results can be seen in FIGs 7A-7D. The curves in these figures represent the access times of the thermistor motor with and without the compensation of this
 20 invention.

FIGs 7A and 7C illustrate a single track average seek time and random average track seek time without the thermistor used according to this invention. FIG 7B and 7D illustrate the maintenance of low access times with changes in temperature if this invention is used.

- From these tests, it can be concluded that the thermistor network will compensate for the resistance
 25 change due to temperature change of the motor windings. Alternatively, the thermistor compensation circuit can be located on a board external to the motor.

- In order to be able to predict how the thermistor circuit will affect the overall resistance if it is mounted on an external board rather than in the motor, testing was done to show how the external board temperature deviates from the motor temperature. For this, tests were done in which the temperatures of the motor and
 30 the external board were monitored for a period of about 70 minutes. The experimental results from these tests can be seen in FIG 8.

From these tests, it can be seen that the drive board stays approximately 10°C hotter than the motor. This was entered into the computer simulation and a new optimum thermistor and shunt combination was found.

- 35 FIG 9 shows a plot of the total resistance (of both the thermistor network and motor coils) versus temperature for the external board mounted thermistor. It can be seen from this plot that with a 20Ω thermistor and a 12Ω shunt resistor, the circuit can be accurately compensated with the thermistor mounted on the drive board.

40 Claims

1. A stepper motor (1) for a disc drive comprising a housing (5), a rotating shaft (2) mounted in said housing (5) for carrying a rotor (3), a plurality of stator coils (28) mounted in parallel on the inner surface of said housing (5), a printed circuit board (36) supported by said housing (5) adjacent exposed ends of said coils (28), and a microprocessor for supplying controlling step pulses to said motor at
 45 periodic intervals established in an open-loop look-up table in a memory associated with said microprocessor, and at least one thermistor (30) mounted on said printed circuit board (36) adjacent said coils (28) and connected to at least one of said coils (28) and responsive to temperature changes in said coils (28) to maintain total motor resistance at a constant level over a range of operating
 50 temperatures of said motor (1), whereby the controlling step pulses applied by said microprocessor accurately position said stepper motor (1) over a wide range of temperatures.
2. A motor (1) for a disc drive as in Claim 1 wherein said motor coils (28) are connected in series pairs, a thermistor (29) connected in series with each of said pairs and mounted adjacent said coils (28) for
 55 sensing the temperature of said coils (28), the resistance of the thermistor (30) changing with temperature to modify the voltage to the coils.



3. A motor (1) for a disc drive as in Claim 2 wherein said coils (28) are circumferentially spaced at regular intervals around the interior surface of said housing (5), said thermistors (30) being connected to each series pair of said coils (28) and supported by said printed circuit board (36) closely adjacent and protruding between said coils (28).

4. A motor (1) for a disc drive as in Claim 3 further including a resistor (32) in parallel with each said thermistor (30).

5. A disc drive, comprising a stepper motor (1) having a housing (5), a rotating shaft (2) mounted in said housing (5) for carrying a rotor (3), a plurality of stator coils (28) mounted within said housing (5), control wires leading to said coils for selective energization thereof for causing rotation of said rotor (3), and a microprocessor for supplying controlling step pulses to said motor (1) at periodic intervals established in an open-loop look-up table in a memory associated with said microprocessor, said drive further comprising a printed circuit board supporting thermistors (30) connected in series with said coils (28) and responsive to temperature changes in said disc drive to maintain total motor resistance at a constant level over a range of operating temperatures of said motor (1), whereby the controlling step pulses applied by said microprocessor accurately position said stepper motor (1) over a wide range of temperatures.

6. A disc drive as in Claim 5 wherein said motor coils (28) are connected in series pairs and one of said thermistors (30) is connected in series with each of said pairs for sensing the temperature in the disc drive, the resistance of the thermistor (30) changing with temperature to modify the voltage to the coils (28).

7. A disc drive as in Claim 6 including a resistor (32) in parallel with each said thermistor (30) to form a thermistor circuit (29) capable of adjusting the performance of the motor (1) with temperature regardless of spacing of the thermistors (30) from the motor coils (28).

Patentansprüche

1. Schrittmotor (1) für einen Plattenantrieb mit einem Gehäuse (5), einer drehenden Welle (2), die zum Tragen eines Rotors (3) in dem Gehäuse (5) angebracht ist, mehreren Statorspulen (28), die parallel an der Innenfläche des Gehäuses (5) angebracht sind, einer Leiterplatte (36), die durch das Gehäuse (5) angrenzend an die freiliegenden Enden der Spulen (28) gehalten wird, und einem Mikroprozessor für ein Zuführen von Steuerschrittpulsen zu dem Motor in periodischen Intervallen, die in einer Tabelle für einen offenen Wirkungskreis in einem Speicher vorgegeben sind, der dem Mikroprozessor zugeordnet ist, und wenigstens einem Thermistor (30), der angrenzend an die Spulen (28) an der Leiterplatte (36) angebracht ist und mit wenigstens einer der Spulen (28) verbunden ist und auf Temperaturänderungen der Spulen (28) anspricht, um den Gesamtwiderstand des Motors auf einem konstanten Wert oberhalb eines Betriebstemperaturbereiches des Motors (1) zu halten, wodurch die durch den Mikroprozessor aufgebrachten Steuerschrittpulse den Schrittmotor (1) in einem weiten Temperaturbereich genau positionieren.
2. Motor für einen Plattenantrieb nach Anspruch 1, bei dem die Motorspulen (28) paarweise in Reihe geschaltet sind, ein Thermistor (29) in Reihe mit jedem der Paare geschaltet und angrenzend an die Spulen (28) zur Erfassung der Temperatur der Spulen (28) angebracht ist, wobei der Widerstand des Thermistors (30) sich mit der Temperatur ändert, um die Spannung an den Spulen zu verändern.
3. Motor (1) für einen Plattenantrieb nach Anspruch 2, bei dem die Spulen (28) in gleichmäßigen Intervallen um die Innenfläche des Gehäuses (5) in Umfangsabstand angeordnet sind, wobei die Thermistoren (30) mit jedem Reihenpaar der Spulen (28) verbunden sind und durch die Leiterplatte (36) nahe neben den Spulen (28) gehalten werden, wobei sie zwischen den Spulen (28) vorstehen.
4. Motor (1) für einen Plattenantrieb nach Anspruch 3, der außerdem einen Widerstand (32) aufweist, der parallel zu jedem Thermistor (30) geschaltet ist.
5. Plattenantrieb mit einem Schrittmotor (1), der ein Gehäuse (5), eine in dem Gehäuse (5) drehende Welle (2) für ein Tragen eines Rotors (3), mehrere innerhalb des Gehäuses (5) angebrachte Statorspu-



len (28), Steuerleitungen, die für eine wahlweise Erregung der Spulen zu diesen führen, um eine Drehung des Rotors (3) zu verursachen, und einen Mikroprozessor für ein Zuführen von Steuerschrittimpulsen zu dem Motor (1) in periodischen Intervallen aufweist, die in einer Tabelle für einen offenen Wirkungskreis in einem Speicher vorgegeben sind, der dem Mikroprozessor zugeordnet ist, wobei der Antrieb außerdem eine Leiterplatte aufweist, die Thermistoren (30) trägt, die in Reihe mit den Spulen (28) geschaltet sind und auf Temperaturänderungen in dem Plattenantrieb ansprechen, um den Gesamtwiderstand des Motors auf einem konstanten Wert oberhalb eines Betriebstemperaturbereiches des Motors (1) zu halten, wodurch die von dem Mikroprozessor aufgetragenen Steuerschrittimpulse den Schrittmotor (1) über einen weiten Temperaturbereich genau positionieren.

6. Plattenantrieb nach Anspruch 5, bei dem die Motorspulen (28) paarweise in Reihe geschaltet sind und einer der Thermistoren (30) in Reihe mit jedem der Paare geschaltet ist, um die Temperatur des Plattenantriebs zu erfassen, wobei sich der Widerstand des Thermistors (30) mit der Temperatur ändert, um die Spannung an den Spulen (28) zu verändern.
7. Plattenantrieb nach Anspruch 6, mit einem Widerstand (32), der parallel zu jedem Thermistor (30) geschaltet ist, um einen Thermistorkreis (29) zu bilden, der ohne Rücksicht auf den Abstand der Thermistoren (30) von den Motorspulen (28) die Wirkungsweise des Motors (1) entsprechend der Temperatur regeln kann.

Revendications

1. Un moteur pas à pas (1) pour une unité de disque comprenant un carter (5), un arbre tournant (2) monté dans le carter (5) pour supporter un rotor (3), un ensemble de bobines de stator (28) montées en parallèle sur la surface intérieure du carter (5), une carte de circuit imprimé (36) supportée par le carter (5) en position adjacente aux extrémités à nu des bobines (28), et un microprocesseur pour appliquer au moteur des impulsions de pas de commande à des intervalles périodiques qui sont établis dans une table fonctionnant en boucle ouverte, dans une mémoire associée au microprocesseur, et au moins une thermistance (30) montée sur la carte de circuit imprimé (36) en position adjacente aux bobines (28) et connectée à l'une au moins des bobines (28) et réagissant à des changements de température dans les bobines (28) en maintenant la résistance totale du moteur à un niveau constant sur une gamme de températures de fonctionnement du moteur (1), grâce à quoi les impulsions de pas de commande qui sont appliquées par le microprocesseur positionnent de façon précise le moteur pas à pas (1) sur une gamme étendue de températures.
2. Un moteur (1) pour une unité de disque selon la revendication 1, dans lequel les bobines (28) du moteur sont connectées par paires en série, une thermistance (29) est connectée en série avec chacune des paires et est montée en position adjacente aux bobines (28) pour détecter la température de ces bobines (28), la résistance de la thermistance (30) changeant avec la température pour modifier la tension qui est appliquée aux bobines.
3. Un moteur (1) pour une unité de disque selon la revendication 2, dans lequel les bobines (28) sont espacées à des intervalles réguliers dans la direction de la circonférence sur la surface intérieure du carter (5), les thermistances (30) étant connectées à chaque paire série de bobines (28) et supportées par la carte de circuit imprimé (36) de façon étroitement adjacente aux bobines (28) et en saillie entre ces dernières.
4. Un moteur (1) pour une unité de disque selon la revendication 3, comprenant en outre une résistance (32) en parallèle avec chaque thermistance (30).
5. Une unité de disque, comprenant un moteur pas à pas (1) ayant un carter (5), un arbre tournant (2) monté dans le carter (5) pour supporter un rotor (3), un ensemble de bobines de stator (28) montées à l'intérieur du carter (5), des fils de commande dirigés vers les bobines pour exciter sélectivement celles-ci de façon à provoquer la rotation du rotor (3), et un microprocesseur pour appliquer au moteur (1) des impulsions de pas de commande à des intervalles périodiques qui sont établis dans une table fonctionnant en boucle ouverte, dans une mémoire associée au microprocesseur, cette unité de disque comprenant en outre une carte de circuit imprimé qui supporte des thermistances (30) qui sont connectées en série avec les bobines (28) et qui réagissent à des changements de température dans



l'unité de disque en maintenant la résistance totale du moteur à un niveau constant sur une gamme de températures de fonctionnement du moteur (1), grâce à quoi les impulsions de pas de commande qui sont appliquées par le microprocesseur positionnent de façon précise le moteur pas à pas (1) sur une gamme étendue de températures.

- 5 6. Une unité de disque selon la revendication 5, dans laquelle les bobines de moteur (28) sont connectées par paires en série, et l'une des thermistances (30) est connectée en série avec chacune des paires pour détecter la température dans l'unité de disque, la résistance de la thermistance (30) changeant avec la température pour modifier la tension qui est appliquée aux bobines (28).
- 10 7. Une unité de disque selon la revendication 6, comprenant une résistance (32) en parallèle avec chaque thermistance (30), pour former un circuit de thermistances (29) capable de régler le fonctionnement du moteur (1) en fonction de la température, indépendamment de l'écartement des thermistances (30) par rapport aux bobines de moteur (28).
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