

PATENT SPECIFICATION

(11) 1 262 763

DRAWINGS ATTACHED

1 262 763

- (21) Application No. 17046/69 (22) Filed 1 April 1969
 (31) Convention Application No. 719 125 (32) Filed 5 April 1968 in
 (33) United States of America (US)
 (45) Complete Specification published 9 Feb. 1972
 (51) International Classification H 02 k 21/14, 1/02
 (52) Index at acceptance H2A 16E 16F 16M 16U 1C7B 1C7D



(54) IMPROVEMENTS IN AND RELATING TO SYNCHRONOUS TIMER MOTORS

(71) We, GENERAL TIME CORPORATION, a Corporation organised and existing under the laws of the State of Delaware, United States of America, residing at Stamford, Connecticut, United States of America, 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 electric motors and, more particularly, to inexpensive, yet, highly efficient synchronous timer motors. Although not limited thereto, the synchronous timer motors according to the invention are particularly useful in battery powered clocks. Synchronous timer motors have been used extensively in electric clocks and other low torque timing applications. In construction, the prior timer motors, often referred to as clock motors, have approached the ultimate in simplicity. The stator normally includes an energizing winding in the form of a simple concentrically wound coil which surrounds part of a stamped magnetic circuit which distributes the magnetic flux in the desired pattern around the rotor. The rotor can be a simple notched disc, or a permanent magnetic disc polarized to have alternating north and south poles around its periphery. Because of the simple structure of these timer motors, they can be readily mass produced in large numbers and the costs per unit can be kept extremely low.

Unfortunately, the simple timer motors of the past have been notoriously inefficient. The efficiency of prior timer motors has normally been less than 1% (see, for example, "Alternating Current Machinery" by Bailey and Gault, McGraw-Hill 1951, pages 334—336) although in some of the better grade timer motors, the efficiency has been as high as 2%.

In the years since the development of the transistor, battery (dry cell) powered clocks have been developed and have become quite

popular. These clocks generally operate by sustaining the reciprocating or oscillatory motion of a balance wheel, tuning fork, pendulum, or the like which in turn mechanically drives the hands of the clock. With these reciprocating and oscillating mechanisms continuous operation for a year or more is achieved without changing or recharging batteries.

Although the use of synchronous clock motors has been widely known for more than 50 years, these motors have not previously been used successfully in battery powered clocks. The use of prior synchronous clock motors was simply not considered feasible because of the known extremely low efficiencies of the motors. The known synchronous clock motors could not approach anything like one year's operation, on, for example, a single "D" size dry cell.

Even the far more expensive synchronous motors of the type including distributed windings could not be used successfully in battery powered clocks. With distributed windings there is a practical limitation as to the number of poles in the motor and, hence, when operating from available frequency sources, they rotate at relatively high speeds which are unacceptable in clocks because of excessive bearing wear and gear noise.

Thus, the more efficient motors with distributed windings were found prohibitively costly and unacceptable for a number of other reasons. The prior known and inexpensive synchronous clock motors were so notoriously inefficient that their use in a battery powered clock was virtually unthinkable.

Yet, a synchronous timer motor drive in a battery powered clock and the like eliminates the need for converting reciprocating motion into rotary motion and, therefore, has the potential of providing a simpler and better timepiece.

According to one aspect of the invention there is provided a synchronous timer motor

comprising a polarized rotating magnet structure including a pair of spaced-apart rotor discs each notched at its periphery to provide a like number of equally spaced rotor teeth, and a permanent magnet located between said discs and so polarized that one of said rotor discs becomes a north pole and the other becomes a south pole; a stator including a core providing pole pieces on diametrically opposite sides of said rotating magnetic structure, each of said pole pieces being shaped to provide a plurality of pole faces, the angular spacing of which is the same as that of said rotor teeth, and an energizing winding coupled to said core to provide an alternating energizing flux which passes only through said rotor discs, said core and a working air gap therebetween, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight.

According to a further aspect of the invention, there is provided a synchronous timer motor comprising an energizing winding adapted to be energized from a controlled frequency AC source; a laminated stator core passing through the centre of said energizing winding and shaped in a magnetically closed configuration providing pole pieces on opposite sides of a working air gap, said air gap including a generally circular bore for receiving a rotor; a pair of laminated, spaced-apart, rotor discs each notched about its periphery to provide a plurality of equally spaced rotor teeth; a disc shaped magnet between said rotor discs, said permanent magnet being polarized axially; an arbor, said rotor discs and permanent magnet being secured to said arbor with the rotor teeth of one of said rotor discs staggered relative to the rotor teeth of the other rotor disc, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight.

The foregoing and other features of the invention may be more readily understood from the following description of a preferred embodiment thereof, by way of example, with reference to the accompanying drawings, in which:—

Figure 1 is a perspective view illustrating the motor with the housing and rotor bearings removed;

Figure 2 is a plan view of the rotor and the surrounding portion of the stator structure;

Figures 3-A and 3-B illustrate, respectively, the magnetic paths for the AC energizing flux and the permanent magnet flux, and

Figure 4 is an enlarged diagram illustrating the relationship between the fluxes passing through the rotor teeth and the adjacent pole faces of the stator.

The synchronous timer motor described in the illustrative embodiment is designed to operate on a 150 hertz supply and rotate at 600 r.p.m. (10 rotations per second). The rotor for this motor includes a permanent mag-

net 10 sandwiched between a pair of notched rotating discs 11 and 12, this assembly being arranged to provide a magnetized rotating circuit for the rotor. Each rotor disc is notched to provide 15 equally-spaced teeth (14 teeth only being shown in the motor illustrated in the drawing) to thereby form a 30-pole motor. The teeth are staggered so that when the rotor is viewed along the axis, as shown in Figure 2, the teeth 16 on one of the discs 11 appear located between adjacent teeth 17 of the other disc 12.

Permanent magnet 10 and discs 11 and 12 are aligned on an arbor 20 between suitable bushings 18 and 19 and secured by an epoxy bond. Epoxy available under the Registered Trade Mark BOND MASTER M-645 (30 parts hardener to 100 parts resin) cured under pressure at a temperature of 300° F has been found to provide satisfactory results.

The permanent magnet is preferably a barium ferrite material such as is available under the trade name LEYMAN IH PLASTIFORM, which is relatively inexpensive in the sizes required for the rotor. The diameter of the permanent magnet is approximately the same as the diameter at the base of the rotor teeth. Permanent magnet 10 is magnetized after the rotor is assembled so that rotor disc 11 becomes a north pole and the disc 12 becomes a south pole. The magnetizing energy is controlled so that the open circuit leakage between discs 11 and 12 is approximately 100 Gauss.

The stator for the motor includes a generally rectangular laminated core configuration having a leg 30 which passes through the centre of an energizing winding 31 as well as pole pieces 32 which pass outside the coil and surround a generally circular opening which accommodates the rotor.

The energizing winding is coaxially wound on a rectangular nylon bobbin 33. Preferably, the winding is centre tapped as can be achieved inexpensively through bifilar winding technique. The length of the completed winding is approximately five times the radius of the winding in order to provide the lowest cost and copper loss. The winding is formed using 39 gage wire and includes 4,500 turns to provide an 880 ohm winding.

The cross-section of leg 30 of the stator core as it passes through the energizing winding has a square configuration as this provides a more efficient coupling relative to the winding. However, in other areas, the stator core need be no thicker than the thickness of the rotor plus a proper allowance for leakage flux. Therefore, to minimize the use of iron in the stator core to thereby reduce costs, the thickness of the stator in all areas other than leg 30 is determined by the leakage flux at a given section and the thickness of the rotor which is approximately .090 inches. Laminations 34 are added to the portion of the stator

25

core passing through the energizing winding to build up the stator core thickness to a square cross-section which is .156 inches on a side.

As can be seen in Figure 1, there is relatively little space between the winding and the stator core as the latter passes around the outside of the winding. By so constructing the stator, the length of the stator magnetic path is minimized thereby reducing iron losses, and the quantity of iron required for construction of the stator is minimized thereby reducing costs.

The portion of the stator core passing outside the energizing coil 31 is separated to provide a permanent air gap in the magnetic circuit between pole pieces 32. This permanent air gap includes the generally circular opening which accommodates the rotor. The periphery of the opening is notched to provide stator pole faces 40 on one side of the opening and stator pole faces 41 on the other side, the angular displacement between adjacent pole face centres being 24° corresponding to the displacement of the 15 teeth on each of the rotor discs. As can be seen in Figures 1 and 2, there are seven stator pole faces on each side of the rotor. The stator pole faces 40 are placed symmetrically relative to the pole faces 41 so that if the teeth 16 of the north pole rotor disc 11 are centred on pole faces 40 on one side of the rotor, the teeth 17 of the south pole rotor disc 12 will be centred on stator pole faces 41 on the other side of the rotor.

When the motor is in operation there are two flux paths, one for the AC energizing coil flux, which is shown schematically in Figure 3-A, and the other for the permanent magnet flux, which is shown in Figure 3-B.

The AC flux is generated by energizing coil 31 and passes through the stator to the stator pole faces, across the air gap, through rotor discs 11 and 12, back across the air gap into the stator to complete the magnetic circuit back to the energizing coil. Significantly, although the rotor includes a permanent magnet, the AC energizing flux does not pass through the permanent magnet. Permanent magnets normally have a high reluctance and therefore substantial iron losses would result if it were necessary for the energizing flux to pass through the permanent magnet. As shown in Figure 3-A, the energizing flux passes through rotor discs 11 and 12 and thereby bypasses the permanent magnet.

The permanent magnet flux path is shown in Figure 3-B and goes from the north pole of permanent magnet 10, through the teeth of rotor disc 11, across the air gap and through the stator pole faces, back across the air gap and through the rotor disc 12 to the south pole of permanent magnet 10. As shown in Figure 2, the teeth of discs 11 and 12 are staggered, but are always sufficiently close to a pole face to complete a magnetic path.

When the motor is rotating synchronously, the teeth are aligned with the stator pole faces generally as shown in Figure 2 when the AC energizing flux is maximum thereby providing maximum coupling between the teeth of discs 11 and 12 through an adjacent stator pole face at the instant of maximum torque generation.

The AC and permanent magnet fluxes combine to provide a substantially greater torque than could be achieved by either hysteresis or reluctance type motors. Since the motor torque is approximately proportional to the square of the flux density in the air gap, the additive effect is quite significant.

Consider first the fluxes during a half cycle when the AC flux (ϕ_a) is in the direction shown in Figure 4. In teeth 16 of the north pole rotor disc, the AC flux (ϕ_a) and the flux (ϕ_m) are additive and represented:

$$\phi_m + \phi_a \quad (1)$$

whereas in the teeth 17, the DC flux (ϕ_m) is in the opposite direction and, therefore, the fluxes oppose one another which can be represented:

$$-\phi_m + \phi_a \quad (2)$$

Since torque is approximately proportional to the square of the flux density, the combined torque T_1 of a pair of rotor teeth 16, 17, is represented:

$$T_1 \propto (\phi_m + \phi_a)^2 - (-\phi_m + \phi_a)^2 \quad (3)$$

which can be multiplied out and simplified to:

$$T_1 \propto 4\phi_m\phi_a \quad (4)$$

During the next half cycle of the AC flux, (ϕ_a), changes direction and, therefore, the torque T_2 during this half cycle is represented:

$$T_2 \propto (\phi_m - \phi_a)^2 - (-\phi_m - \phi_a)^2 \quad (5)$$

which can be multiplied out and simplified to become:

$$T_2 \propto 4\phi_m\phi_a \quad (6)$$

Thus, the motor torque is approximately proportional to four times the product of the permanent magnet flux and the energizing flux. From this relationship, it should be noted that the torque increases in direct proportion to increases in the permanent magnetic flux. However, the saturation characteristics in the most confined portions of the magnetic paths (the rotor teeth and stator pole faces) limit the amount of torque multiplication which can be achieved by increasing the strength of the permanent magnet. It has been found desirable to design the motor to operate in a range not normally exceeding 50% of the permissible saturation flux density

when the permanent magnet flux and peak AC energizing flux are combined. In the motor according to the invention, the permanent flux (Φ_m) is approximately ten times as great as the peak energizing flux (Φ_e) which, according to equations (4) and (6) provide a motor torque approximately 40 times greater than could be achieved without the polarized magnetic rotating circuit.

The magnetic material for the stator circuit and the rotor discs 11 and 12 should be carefully selected.

The magnetic material must have a high permeability which, for the purposes of this specification, can be defined as being in excess of 20,000.

The magnetic material must also have a high saturation flux density so that a significant torque multiplication can be achieved through the use of the permanent magnet flux without requiring an abnormally large structure. For the purposes of this specification, high saturation flux densities are defined as saturation densities exceeding 10,000 Gauss.

It is further essential that the magnetic material have a relatively small hysteresis loop so that the hysteresis losses at the motor operating frequency are maintained within bounds. For the purposes of this specification, a low hysteresis material can be defined as one in which the hysteresis loss is below 500 ergs/cc/cycle. Preferably, the magnetic material has a hysteresis loss below 300 ergs/cc/cycle.

An iron alloy magnetic material consisting of at least a 40% nickel content (by weight) has been found to provide a desired combination of high permeability and high saturation flux density as well as a low hysteresis loss. Preferably, the nickel content is maintained between 47—50%. Such materials have a permeability of approximately 50,000, a saturation flux density of 16,000 Gauss and a hysteresis loss of approximately 500 ergs/cc/cycle.

In an efficient dry cell powered synchronous motor, the eddy current losses must also be reduced to a minimum. To achieve this, the magnetic material is selected having a relatively high electrical resistivity which, for the purposes of this application, can be defined as a resistivity greater than 60 microhm-cm. Preferably, the resistivity is within the range of 75—90 microhm-cm. High resistivity is achieved in the magnetic material through the addition of silicon or molybdenum but the addition of silicon or molybdenum has been found to adversely affect the magnetic material's permeability and saturation flux density, while, on the other hand, having the desirable effect of reducing the hysteresis losses. Between 1% and 5%, preferably about 3% (by weight) of either molybdenum or silicon is found to increase the resistivity into the preferable range without precluding the high

permeability or high saturation flux density characteristics of the material. The addition of approximately 3% silicon or molybdenum also has been found to reduce the hysteresis losses into the desirable range of below 300 ergs/cc/cycle.

Relatively thin laminations are utilized to further reduce eddy current losses. Iron-nickel alloy materials with a thickness of approximately six one-thousandths of an inch (0.006) can be produced at moderate cost and, hence, laminations of this thickness were selected for the motor in the illustrative embodiment.

The selection of relatively thin laminations on the order of six one-thousandths of an inch is significant for another reason. In the design of a motor, it is desirable to minimize the air gap. However, small air gap tolerances are usually achieved by resorting to more expensive machining and construction techniques, which are generally quite costly. For inexpensive timer motors, the rotor and stator laminations are preferably produced using stamping techniques. With thin laminations on the order of six one-thousandths of an inch, the stator and rotor laminations can be punched at moderate cost using high-speed progressive carbide dies while maintaining the maximum air gap within five one-thousandths of an inch (0.005). This is achieved in specifying suitable plus tolerances for the rotor discs and minus tolerances for the stator bore so that as the dies wear the air gap will be reduced and therefore the air gap never exceeds five-thousandths of an inch. Thus, by using very thin laminations not only are the eddy current losses reduced, but a small air gap can be achieved at moderate cost.

The laminations of the stator core on one side of the rotor are the same as those on the other side and, hence, can be made from the same stampings. Preferably, however, the lengths of the portions passing through the energizing coil are varied in length to provide a lap joint rather than a butt joint. The lap joint reduces reluctance of the magnetic path.

Considerable care must be taken to minimize stray power losses which arise when the flux density (B) becomes too high. The hysteresis loss is proportional to ($B^{1.6}$) and copper losses are generally proportional to (B^2). An undesirable high flux density (B) can occur if the permanent magnet flux is too high, or the size of the rotor teeth and stator pole faces too small. The wave shape of the motor energizing signal is also very significant. A sine wave source is preferable and a square wave source quite acceptable. However, wave forms having periodic spikes, such as those caused by switching transients, are very undesirable since they create disproportionately high stray losses.

The following data has been obtained for a motor constructed according to the invention

with a 3/8 inch nominal rotor diameter, an air gap not exceeding five thousandths of an inch, magnetic laminations six thousandths of an inch and the magnetic material being an iron alloy including 47% (by weight) nickel and 3% (by weight) molybdenum. This magnetic material is found to have a permeability of 30,000, a resistivity of 90 microhm-cm, a saturation flux density of 11,000 Gauss and a hysteresis loss of 250 ergs/cc/cycle. When energized from a 150 hertz sine wave source, the following characteristics were measured:

E	I	W _{in}	W _{out}	Efficiency
volts	micro amps	micro watts	micro watts	%
.76	135	84	50	60
.80	145	110	77	70
.95	150	139	95	65

When the same motor was operated from a 150 hertz square wave source, the following characteristics were measured:

E	I	W _{in}	W _{out}	Efficiency
d.c. volts	micro amps	micro watts	micro watts	%
1.2	440	529	275	52
1.5	545	816	355	43.6

It will be noted that the motor illustrated is not significantly more complex than prior synchronous timer motors, and is not significantly more costly. The motor can easily include a large number of poles and, hence, can operate at the desired relatively low rotational speeds. Such a motor has been found capable of continuously driving a clock movement for more than a year on a single "D" cell utilising D.C. to A.C. conversion as disclosed in our copending application No. 17047/69 (Serial No. 1,262,764) and of achieving an operating efficiency of better than 40% under adverse conditions.

While only one illustrative embodiment has been described in detail, it should be obvious that there are numerous variations within the scope of the invention as defined in the appended claims.

WHAT WE CLAIM IS:—

1. A synchronous timer motor comprising a polarized rotating magnetic structure including a pair of spaced-apart rotor discs each notched at its periphery to provide a like number of equally spaced rotor teeth, and a permanent magnet located between said discs and so polarized that one of said rotor discs becomes a north pole and the other becomes a south pole; a stator including a core providing pole pieces on diametrically opposite sides of said rotating magnetic structure, each of said pole pieces being shaped to provide a plurality

of pole faces, the angular spacing of which is the same as that of said rotor teeth, and an energizing winding coupled to said core to provide an alternating energizing flux which passes only through said rotor discs, said core and a working air gap therebetween, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight.

2. A synchronous timer motor comprising an energizing winding adapted to be energized from a controlled frequency AC source; a laminated stator core passing through the centre of said energizing winding and shaped in a magnetically closed configuration providing pole pieces on opposite sides of a working air gap, said air gap including a generally circular bore for receiving a rotor; a pair of laminated, spaced-apart, rotor discs each notched about its periphery to provide a plurality of equally spaced rotor teeth; a disc shaped magnet between said rotor discs, said permanent magnet being polarized axially; an arbor, said rotor discs and permanent magnet being secured to said arbor with the rotor teeth of one of said rotor discs staggered relative to the rotor teeth of the other rotor disc, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight.

3. A motor as claimed in claim 1 or 2 wherein said nickel content in said iron alloy

density
dition of
um also
is losses
rgs/cc/

70

lized to
n-nickel
pproxi-
(0.006)
hence,
ted for
nt.

75

inations
an inch
design
the air
es are
re ex-
tech-

80

y. For
stator
using
ons on
ch, the
hed at
ressive
imum
n inch
suit-

85

and
o that
duced
five-
very
current
an be

90

n one
n the
n the
the
the
wide
The
netic

95

imize
flux
eresis
losses
desir-
f the
the
faces
ener-
sine
wave
orms
used
able
stray

100

for
ation

105

for
ation

110

for
ation

115

for
ation

120

for
ation

125

for
ation

130

27

flux density
addition of
denum also
resis losses
0 ergs/cc/ 70
utilized to
Iron-nickel
f approxi-
ch (0.006) 75
nd, hence,
ected for
ment.
aminations
of an inch 80
the design
ze the air
ances are
more ex-
on tech- 85
ostly. For
nd stator
ed using
ations on
inch, the 90
nched at
ogressive
maximum
an inch
2 suit- 95
-es and
so that
reduced
eds five- 100
ing very
current
can be
on one 105
on the
rom the
er, the
ugh the
rovide
The 110
magnetic
imize
he flux
steresis 115
r losses
ndesir-
if the
or the
e faces 120
r ener-
A sine
e wave
forms
caused 125
sirable
1 stray
ed for
ention 130

with a 3/8 inch nominal rotor diameter, an air gap not exceeding five thousandths of an inch, magnetic laminations six thousandths of an inch and the magnetic material being an iron alloy including 47% (by weight) nickel and 3% (by weigh) molybdenum. This mag-
netic material is found to have a permeability of 30,000, a resistivity of 90 microhm-cm, a saturation flux density of 11,000 Gauss and a hysteresis loss of 250 ergs/cc/cycle. When energized from a 150 hertz sine wave source, the following characteristics were measured: 10

E	I	W _{in}	W _{out}	Efficiency
volts	micro amps	micro watts	micro watts	%
.76	135	84	50	60
.80	145	110	77	70
.95	150	139	95	65

When the same motor was operated from a 150 hertz square wave source, the following characteristics were measured: 15

E	I	W _{in}	W _{out}	Efficiency
d.c. volts	micro amps	micro watts	micro watts	%
1.2	440	529	275	52
1.5	545	816	355	43.6

It will be noted that the motor illustrated is not significantly more complex than prior synchronous timer motors, and is not significantly more costly. The motor can easily include a large number of poles and, hence, can operate at the desired relatively low rotational speeds. Such a motor has been found capable of continuously driving a clock movement for more than a year on a single "D" cell utilising D.C. to A.C. conversion as disclosed in our copending application No. 17047/69 (Serial No. 1,262,764) and of achieving an operating efficiency of better than 40% under adverse conditions. 20
of pole faces, the angular spacing of which is the same as that of said rotor teeth, and an energizing winding coupled to said core to provide an alternating energizing flux which passes only through said rotor discs, said core and a working air gap therebetween, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight. 55

While only one illustrative embodiment has been described in detail, it should be obvious that there are numerous variations within the scope of the invention as defined in the appended claims. 25
2. A synchronous timer motor comprising an energizing winding adapted to be energized from a controlled frequency AC source; a laminated stator core passing through the centre of said energizing winding and shaped in a magnetically closed configuration providing pole pieces on opposite sides of a working air gap, said air gap including a generally circular bore for receiving a rotor; a pair of laminated, spaced-apart, rotor discs each notched about its periphery to provide a plurality of equally spaced rotor teeth; a disc shaped magnet between said rotor discs, said permanent magnet being polarized axially; an arbor, said rotor discs and permanent magnet being secured to said arbor with the rotor teeth of one of said rotor discs staggered relative to the rotor teeth of the other rotor disc, said rotor discs and said stator core being constructed from an iron alloy including at least 40% nickel by weight. 60
3. A motor as claimed in claim 1 or 2 wherein said nickel content in said iron alloy 65

WHAT WE CLAIM IS:—

1. A synchronous timer motor comprising a polarized rotating magnetic structure including a pair of spaced-apart rotor discs each notched at its periphery to provide a like number of equally spaced rotor teeth, and a permanent magnet located between said discs and so polarized that one of said rotor discs becomes a north pole and the other becomes a south pole; a stator including a core providing pole pieces on diametrically opposite sides of said rotating magnetic structure, each of said pole pieces being shaped to provide a plurality 70
75
80



is between 47% and 50% (by weight).

4. A motor as claimed in any preceding claim wherein said iron alloy further includes from 1% to 5% (by weight) of silicon or molybdenum.

5. A motor as claimed in claim 4 wherein said iron alloy includes approximately 3% (by weight) of silicon or molybdenum.

6. A motor as claimed in claim 3 or 4 wherein said iron alloy includes (by weight) approximately 47% nickel and 3% molybdenum.

7. A motor as claimed in claim 1 or any one of claims 3 to 6 when appendent thereto wherein said rotor discs and said stator core are laminated, high permeability, magnetic structures so arranged that the permanent magnet and energizing fluxes have low loss iron paths through the magnetic structures of high permeability so that all the magnetomotive force is across the air gap.

8. A motor as claimed in any preceding claim wherein said rotor discs and stator core have a saturation density in excess of 10,000 Gauss.

9. A motor as claimed in claim 8 wherein said permanent magnet flux is approximately ten times greater than the peak energizing flux as said fluxes pass through the teeth of said rotor discs.

10. A motor as claimed in claim 8 or 9 wherein the maximum flux density created by the combined permanent magnet and energizing fluxes is less than 50% of the saturation density of the rotor discs and stator core.

11. A motor as claimed in any preceding claim wherein said rotor discs and stator core have a resistivity greater than 60 microhm-cm.

12. A motor as claimed in claim 11 wherein said rotor discs and stator core have a resistivity in the range between 75—90 micro-cm.

13. A motor as claimed in any preceding claim wherein said rotor discs and stator core have a hysteresis loss of less than 500 ergs/cc/cycle.

14. A motor as claimed in claim 13 wherein

said rotor discs and stator core have a hysteresis loss of less than 300 ergs/cc/cycle.

15. A motor as claimed in claim 2 or 7 or any one of claims 8 to 14 inclusive when appendent thereto wherein said laminated rotor discs and stator core consist essentially of laminations each no greater than 0.006 inches thick.

16. A motor as claimed in any preceding claim wherein said working air gap is less than 0.005 inches.

17. A motor as claimed in claim 16 wherein the laminations for said stator core and said rotor discs are made by stamping from magnetic material.

18. A motor as claimed in any preceding claim wherein the rotor discs and stator core are fabricated of a magnetic material having a permeability greater than 20,000.

19. A motor as claimed in claim 2 wherein said rotor discs and stator core laminations are fabricated of a magnetic material which has a permeability of approximately 30,000, a saturation density of approximately 11,000 Gauss, a hysteresis loss of approximately 250 ergs/cc/cycle and a resistivity of approximately 90 microhm-cm.

20. A motor as claimed in any one of claims 2 to 6 or of claims 8 to 19 inclusive wherein the stator core has a substantially square cross-section where it passes through the energizing winding.

21. A motor as claimed in any preceding claim, wherein the energizing winding is co-axially wound on a bobbin and has a length approximately five times the radius thereof.

22. A synchronous timer motor substantially as hereinbefore described with reference to the accompanying drawing.

23. A battery operable clock including a motor as claimed in any preceding claim.

For the Applicant,
SORRELL & SON,
Chartered Patent Agents,
Otham,
Maidstone, Kent.

