

[54] **ELECTROMAGNETIC TIMING MECHANISM**

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[51] Int. Cl. **G04c 3/00, G04c 3/04**

[58] Field of Search **58/28 R, 23 D, 23 TF, 58/23 V, 29-32; 310/36, 37, 38, 39; 318/134, 696**

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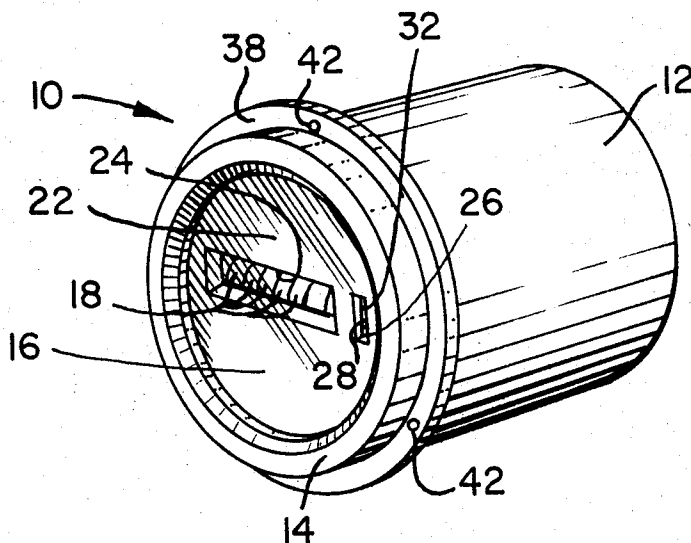
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Assistant Examiner—Stanley J. Witkowski
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[57] **ABSTRACT**

A timing mechanism employs a rotary oscillatory member which is biased toward a neutral position and is pulsed electromagnetically in one direction about its axis so that it oscillates at a selected natural frequency. The timed oscillations of the member may be transformed into unidirectional motion of a second rotary member. This second member may then drive counting wheels which provide a visual indication of time as measured from a selected time base.

31 Claims, 8 Drawing Figures



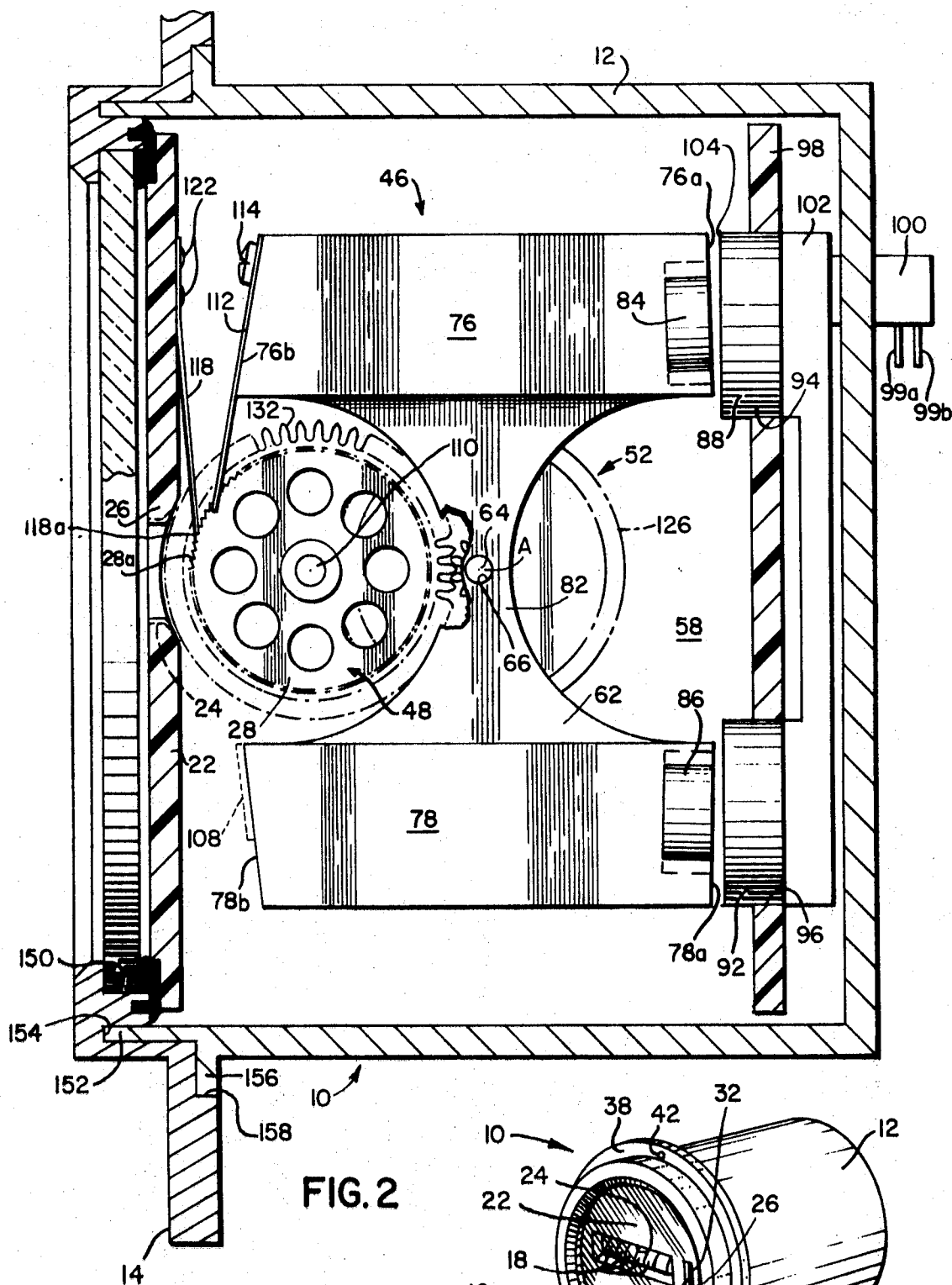


FIG. 2

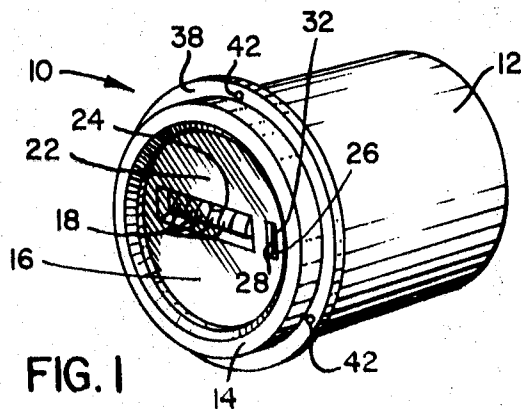


FIG. 1

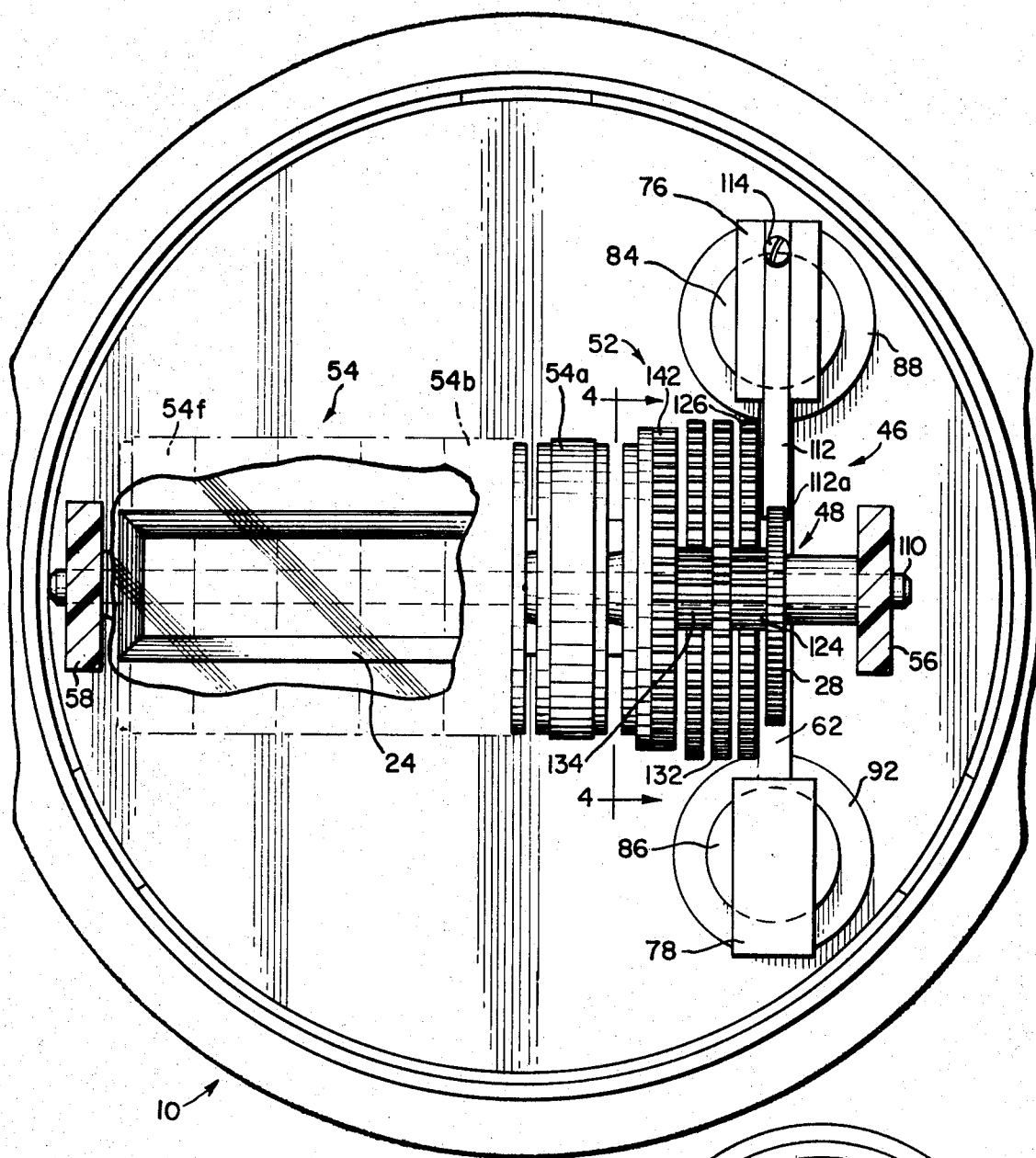


FIG. 3

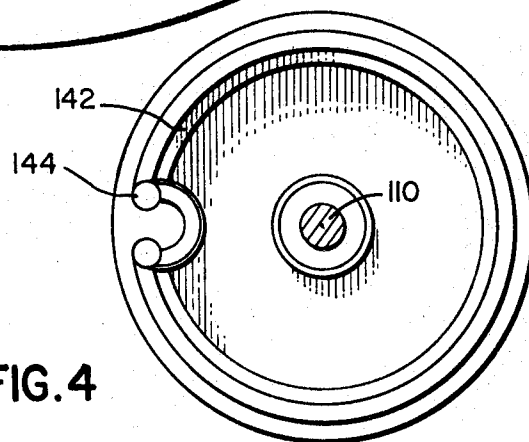


FIG. 4

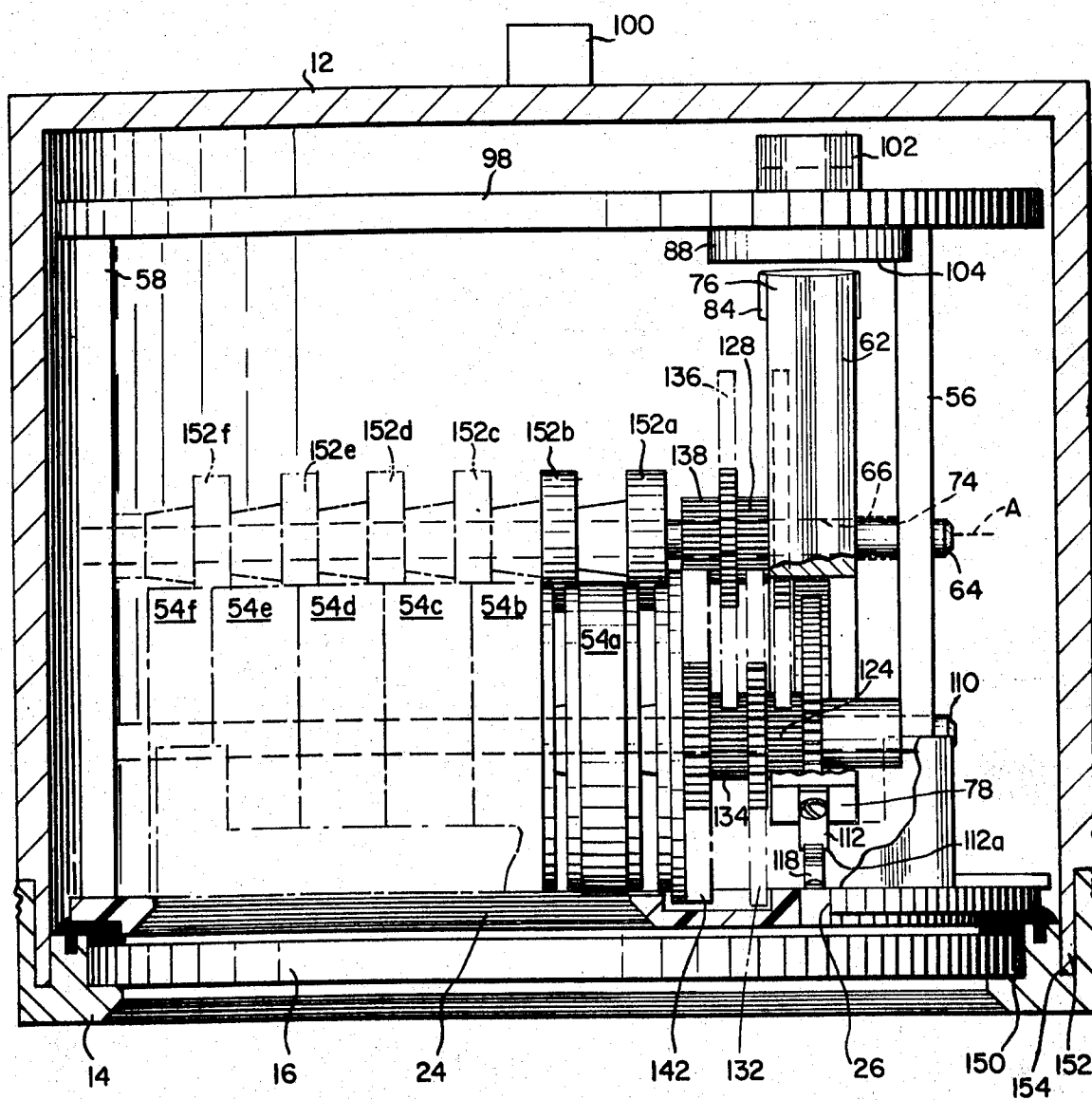


FIG. 5

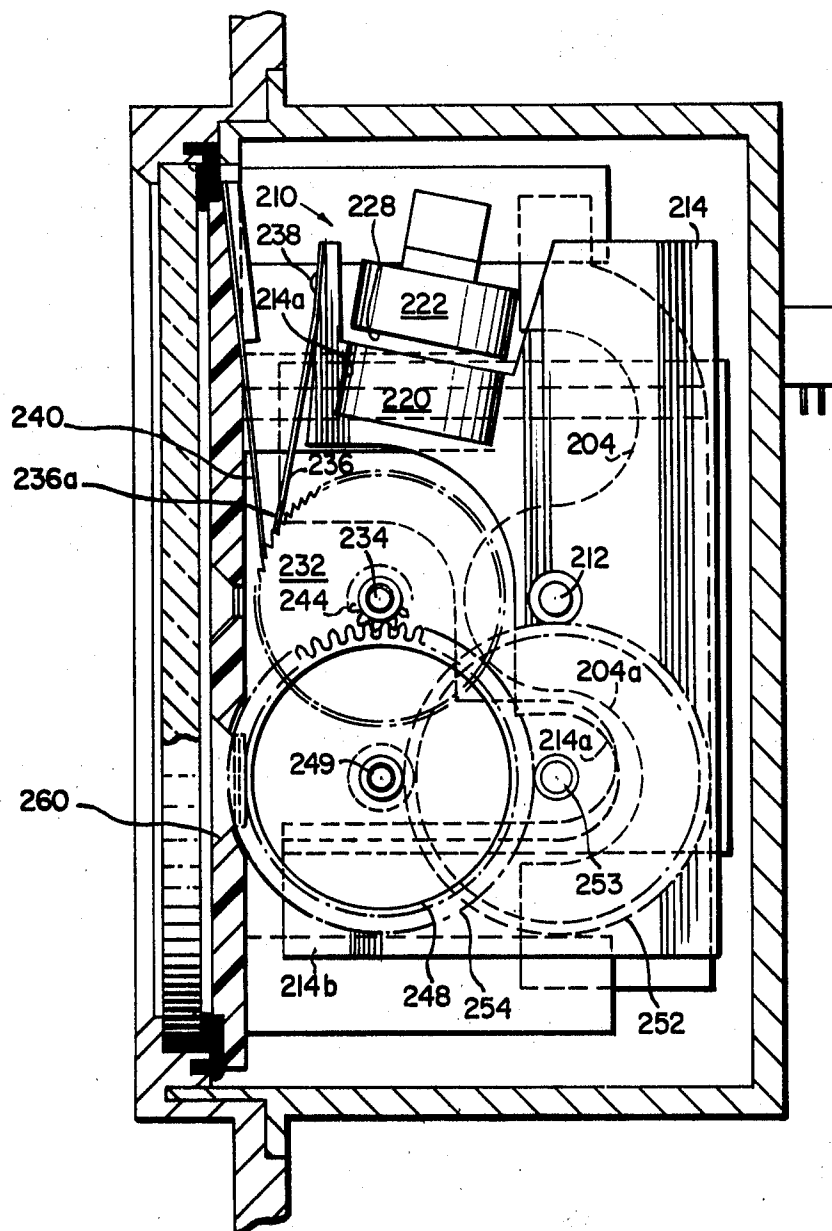


FIG. 6

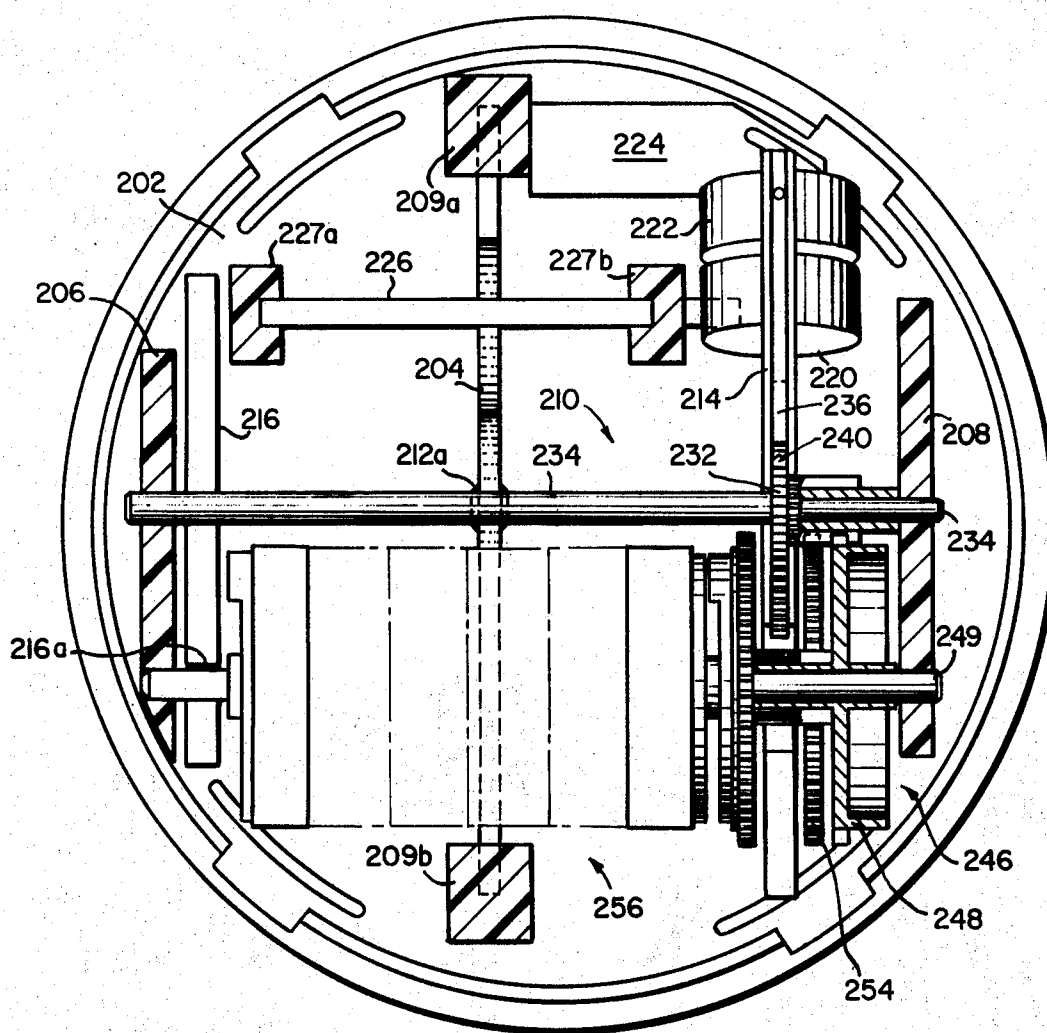


FIG. 7

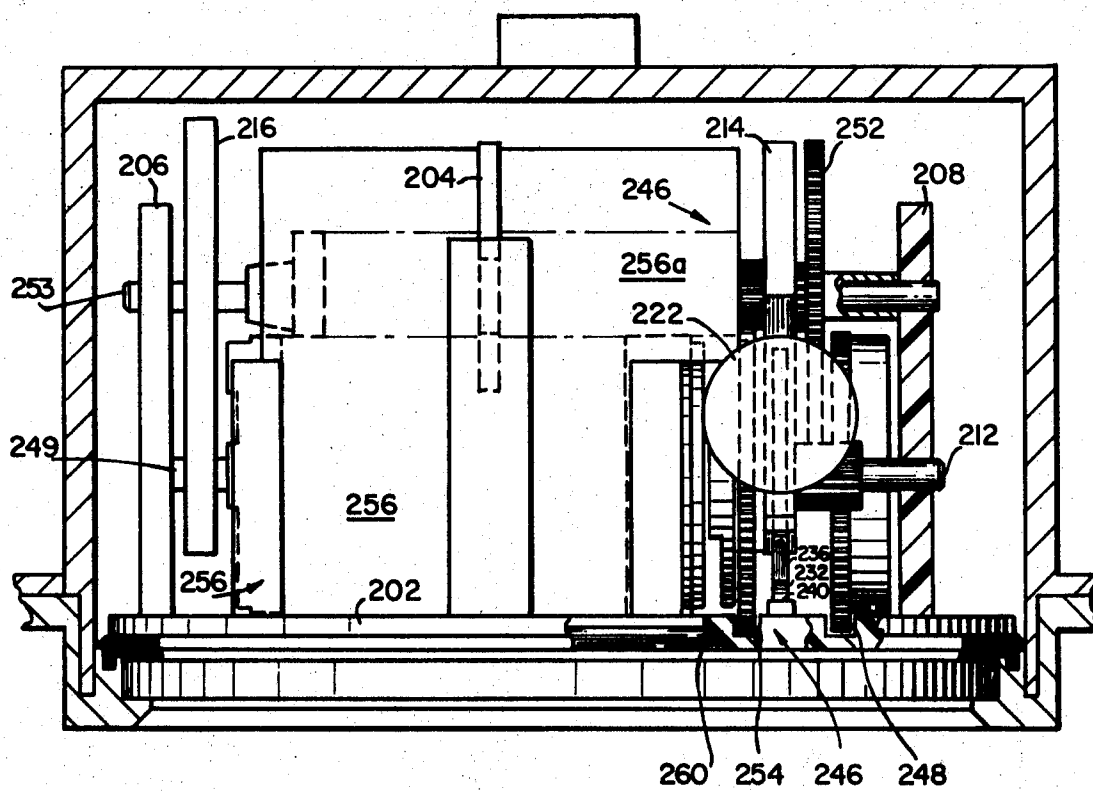


FIG. 8

ELECTROMAGNETIC TIMING MECHANISM**BACKGROUND OF THE INVENTION**

This invention relates to an electromagnetically driven timing mechanism. It relates more particularly to a mechanism of this type incorporating a mechanical oscillatory member which is pulsed electromagnetically so that it oscillates at a selected natural frequency. The mechanism may indicate time directly or it may perform various clocking and timing functions.

Electromagnetically driven mechanical oscillators generally are, of course, well-known. Probably the most prevalent type is the tuning fork vibrator disclosed in U.S. Pat. No. 2,900,786 and related patents. Generally, these tuning fork oscillators operate at relatively high frequencies and are relatively expensive to make. Also, they are sensitive to shock forces. Consequently, they are used primarily as the frequency source in expensive time pieces which are not likely to be subjected to rugged use.

A second type of electromagnetically driven mechanical oscillator is used in very inexpensive clocks and display devices. Basically, this type consists of a pendulum having a transverse arm attached to the pendulum above the pivot point. This arm is made of a ferromagnetic material and extends into a wire coil. When a current pulse is applied to the coil, the arm is repelled, causing the pendulum to swing in one direction. The pendulum then swings in the opposite direction under the influence of gravity. The movement of the pendulum controls a switch which applies a current pulse to the coil each time the pendulum reaches the end of its return swing. Thus, the oscillations of the pendulum are sustained as long as the current pulses are applied to the coil.

This latter type of vibrator is disadvantaged because it requires a relatively large volume to accommodate the swinging pendulum. Also, it has a low mechanical Q. Therefore, its oscillation frequency is not particularly accurate. Further, it is very susceptible to vibration and shock force. Another drawback of these prior low-frequency oscillatory systems is the fact that their oscillations do not commence automatically when excitation pulses are applied. Rather, they must be started manually.

The problems noted above militate against the use of these prior oscillators as the control elements of elapsed time indicators with which we are particularly concerned here. These indicators are used on vehicles such as aircraft, tractors, boats and the like, to measure elapsed time for maintenance and warranty purposes. The indicator should be a relatively inexpensive throw-away item which is installed on the vehicle and turned on when the vehicle is leased or purchased. Also, it is expected to run reliably for the life of the vehicle even though it is subjected to a variety of vibrational and shock forces. As a practical matter, then, conventional electromagnetically driven oscillators are not used for this purpose. Rather, the indicators are controlled by conventional balance wheel timing mechanisms which are themselves far from satisfactory for this purpose.

SUMMARY OF THE INVENTION

Accordingly, this invention aims to provide an electromagnetically driven mechanical oscillator having a relatively stable frequency of oscillation.

Another object of the invention is to provide a mechanical oscillator of this type having a relatively long die-down time (i.e. low rate of decay).

A further object of the invention is to provide a mechanical oscillator of this type which starts automatically as soon as driving pulses are applied.

A further object of the invention is to provide an electromagnetically driven mechanical oscillator which requires a minimum amount of excitation energy.

Yet another object of the invention is to provide an oscillator of this type having minimum internal energy losses.

A further object is to provide an oscillator for a timing mechanism having a relatively high mechanical Q.

Still another object of this invention is to provide a timing mechanism which is powered by an electromagnetically driven mechanical oscillator which is relatively immune to externally applied vibratory and shock forces.

A further object of the invention is to provide a timing mechanism composed of a unidirectional rotary member which is driven by the oscillator described above wherein there is a maximum amount of useful energy transferred between the oscillator and the rotary member.

Still another object of the invention is to provide a clock or elapsed time indicator composed of the above-described oscillator and rotary member which has a relatively long, useful life.

Yet another object is to provide a timing mechanism which requires no maintenance and is very inexpensive to make.

Another object of the invention is to provide such an indicator which is rugged and reliable and capable of sustaining the violent shocks to which it is subjected when installed on present-day, off-highway equipment.

Other objects will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereinafter set forth and the scope of the invention will be indicated in the claims.

Briefly, the heart of the present timing mechanism is an electromagnetically pulsed rotary oscillatory member. The mass of this member is symmetrically disposed about a center point and spaced therefrom so that the member has an appreciable moment of inertia. The member is pivotally supported on a base and it is spring-biased toward a neutral position on its pivot.

In a preferred embodiment, the member is secured at its center of mass to one end of a relatively stiff torsion spring which is anchored to the base so that the member can oscillate about an axis coinciding with the axis of the spring at a selected natural frequency. Thus, the spring provides both the support and bias for the oscillatory member.

The member is excited to oscillation by a brief magnetic force which is applied to its periodically at a frequency approaching the natural frequency of the member. The application of this force is controlled by a sensing coil arrangement which senses the position of the member and generates an electrical signal. The signal is amplified and then used to generate the pulsed magnetic force which drives the member. Thus, the excitation force is applied at just the right instant to keep the member oscillating at a selected, precise frequency.

The subject oscillator has minimal inherent energy losses. Therefore, its die-down time is relatively long. In other words, if the excitation forces cease, the member keeps oscillating at a frequency which remains essentially the same for a relatively long period of time, on the order of 30 to 60 seconds. Thus, the oscillator operates efficiently and has a relatively high Q. Accordingly, it is particularly suitable for use as a clock or frequency standard in an electrical circuit to control the occurrence of events. Also, the movements of the oscillatory member can perform other timed functions. For example, a mirror affixed to the oscillatory member can periodically reflect a light beam to a selected point. The same member can be used to interrupt such a beam so that it, in effect, functions as a light chopper.

In the present instance, the oscillator is shown as part of a clock or, more particularly, an elapsed time indicator. Accordingly, the timing mechanism includes a motion transformer which converts the oscillatory motion of the oscillatory member to unidirectional motion for actuating the clock movement. More particularly, the oscillatory member carries a driving pawl which engages the teeth of a ratchet wheel rotatively mounted adjacent the member. The amplitude of the oscillations of the member are within a range wherein the stroke of the pawl in a direction essentially tangent to the ratchet wheel is at least as great as the pitch of the ratchet teeth, but not greater than twice this pitch. Thus, each oscillation of the member causes the pawl to advance the ratchet wheel one tooth so that the rotational speed of the ratchet wheel is exactly proportional to the frequency of oscillation of the rotary member. Since the oscillation frequency can be maintained quite constant, as noted above, the rotational speed of the ratchet wheel driven thereby is similarly stabilized.

The ratcheting mechanism also includes a retaining pawl which engages the ratchet teeth to prevent backup of the wheel. Ideally, the driving and retaining pawls are arranged so that when the wheel is at rest, the retaining pawl butts a tooth of the wheel while the drive pawl lies approximately halfway across a tooth. This insures that the driving pawl and oscillatory member are lightly loaded initially so that, as soon as the excitation pulses are applied, the member will start to oscillate automatically and accelerate to maximum amplitude in a minimum time. This is particularly important in the case of an elapsed time indicator because the unit must start reliably without any manual excitation of the oscillatory member and start driving the ratchet wheel immediately so that the indicator keeps accurate time.

The ratchet wheel is coupled through a gear reduction stage to a train of counting wheels. Thus, continued rotation of the ratchet wheel causes the counting wheels to display the time interval during which the mechanism has been in operation. The presence of the gear reduction stage effectively decouples the oscillatory member from the counter so that the presence of the counter wheels has no effect appreciable on the oscillator frequency.

The entire timing mechanism is supported within a sealed housing which both protects the mechanism from dust and the elements and also insulates it to some extent from vibration and shock forces. Accordingly, the unit operates reliably for a relatively long period even under the most adverse conditions. Yet, the unit is inexpensive to make and requires no maintenance.

BRIEF DESCRIPTION OF THE DRAWINGS

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 is an isometric view of an elapsed time indicator embodying the principles of this invention;

FIG. 2 is a vertical sectional view with some parts shown in elevation of the FIG. 1 indicator;

FIG. 3 is a front elevational view with parts cut away thereof;

FIG. 4 is a sectional view along line 4—4 of FIG. 3;

FIG. 5 is a top view with parts cut away thereof;

FIG. 6 is a vertical sectional view like FIG. 2 of another embodiment of the invention;

FIG. 7 is a front elevational view with parts cut away thereof; and

FIG. 8 is a top view with parts cut away thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning now to FIG. 1 of the drawings, the components of the elapsed time indicator are contained in a rugged housing shown generally at 10 made of a suitable, impact-resistant material such as metal, plastic or the like. Housing 10 comprises a generally cylindrical casing 12 and a circular bezel 14. The clock time is visible through a transparent window 16 supported by the bezel.

A set of six numbered wheels 18 mounted on a base plate 22 inside the housing indicates the elapsed time. A slot 24 is provided in plate 22 so that the numbers on these wheels are visible through the window. Depending upon the particular application, the wheels 18 can be geared together so that they all indicate elapsed time in hours or the two right-hand wheels can be arranged to indicate minutes with the remaining four wheels showing elapsed hours.

A second slot 26 is provided in plate 22 to the right of slot 24. A ratchet wheel 28 carrying a bench mark 32 is visible through slot 26. As long as the indicator is operating, this fact is apparent by the bench mark 32 appearing in slot 26 every few seconds or so.

The indicator is designed to be mounted in a suitable opening in a dashboard or other type of panel. This opening should be large enough to receive casing 12. Bezel 14 is provided with a flange 38 arranged to overhang the opening wall and holes 42 are provided in the flange through which screws may pass to secure the indicator to the panel. Alternatively, the indicator can be clamped to the panel in the manner of conventional automobile clocks and accessories. In this event, the flange 38 can be made much narrower.

Turn now to FIGS. 2 and 3 which show one embodiment of the indicator. The moving parts of the mechanism are all contained inside the housing 10. These comprise a mechanical oscillator shown generally at 46, a motion transformer indicated at 48, a gear reduction stage shown at 52 and a counter section indicated at 54. All of these elements are mounted on two tabs 56 and 58 projecting out from the rear face of base plate 22 (FIGS. 3 and 5). Furthermore, all of these components are situated along only two parallel axis between the two tabs.

Oscillator 46 comprises a rotary oscillatory member 62 which is mounted near one end of a relatively long,

stiff torsion spring 64, the other end of which is anchored in tab 58. The spring extends through a small central opening 66 at the center of member 62 with the spring and member being bonded at this point so that they rotate together. The opposite end of the spring is anchored to tab 58 by being clamped between the top of the tab and a yoke 68 which is pressed down against the tab by screws 72. In order to prevent off-axis vibrations of the spring, its free end beyond member 62 is rotatively received in an opening 74 in tab 56 (FIG. 5). The spring 64 is sufficiently long that the rotary oscillations of the member are not translated to a vibrating mode.

Member 62 includes a pair of relatively massive portions 76 and 78 symmetrically disposed on opposite sides of the axis A of spring 64. These portions are connected by a relatively narrow web 82 containing the opening 66. In the illustrated embodiment, member 62 is made of brass and its portions 76 and 78 are generally trapezoidal in shape for reasons to be discussed later. However, the member could just as well be molded of plastic with weights being contained in portions 76 and 78. The objective is simply to have appreciable mass spaced symmetrically from axis A so that the member 62 has a relatively high moment of inertia.

With the member in the position shown in FIG. 2, spring 64 is in its unstressed state. However, when the member is rotated through a small angle in one direction or another about axis A, the spring winds up so that it exerts a restoring force on the member, tending to return it to its FIG. 2 position. Accordingly, when so deflected, member 62 tends to oscillate about axis A at a natural frequency dependent upon its moment of inertia and the spring constant of spring 64.

Referring to FIGS. 2, 3 and 5 member 62 is excited to oscillation electromagnetically. More particularly, a pair of discoid permanent magnets 84 and 86 are recessed into the corresponding ends of 76a and 78a of member portions 76 and 78. Further, a pair of drive coils 88 and 92 are mounted opposite these magnets in openings 94 and 96 in a printed circuit board 98. Board 98 carries an electronic drive circuit (not shown) which applies current pulses to coils 88 and 92 at timed intervals. Power is coupled to the drive circuit by way of terminals 99a and 99b protruding from a raised boss 100 on the back of casing 12. A suitable drive circuit is shown, for example, in the aforesaid U.S. patent.

A magnetic shunt, to wit a strip 102 of iron, extends between coils 88 and 92 behind circuit board 98 so that the fields developed by coils 88 and 92 are additive. Thus, when current pulses are applied to the coils 88, a magnetic force couple is applied to member 62, causing it to rotate in one direction, i.e. counterclockwise about axis A in FIG. 2. This causes the torsion spring 64 to wind up so that it biases the member 62 in the opposite direction, i.e. clockwise in FIG. 2.

We should mention that the end faces 76a and 78a of portions 76 and 78 are cut on a bias, so that when these portions are closest to the coils, the magnets are parallel to the ends of the coils. This maximizes the magnetic forces coupled to the member.

The excitation pulses are applied while member 62 is engaged with and driving the motion transformer 48 (FIG. 5). More particularly, a phase sensing coil 104 is situated adjacent coil 88. Each time member 62 approaches the centerpoint of its clockwise rotation, the movement of magnet 84 induces a current pulse in coil

104. This current pulse is amplified and applied to the drive coils 88 and 92. Thus, the magnetic pulses which drive member 62 are locked in phase with the oscillator frequency by sensing the position of the magnet 84. Actually, for best results, the natural frequency of the electronic drive circuit should be somewhat less than that of the frequency of the mechanical oscillator (e.g. 90 percent) to be sure that the natural frequency of member 62 is determinative of the oscillation frequency.

Because of its design, oscillator 46 has a relatively high Q. Also, its oscillations decay very slowly when the excitation pulses cease. This enables the oscillator 46 itself to function as an accurate clock to control various timing or sequencing operations. For example, part of the alternating current induced in sensing coil 104 when the system is operating can be tapped off, amplified and used to generate trigger pulses for electronic control purposes. In another application, a mirror indicated in dotted lines at 108 can be affixed to the oscillator end face 78b so that when a beam of light is reflected from mirror 108 to a surface, the beam is caused to scan across that surface at a controlled rate.

As best seen in FIG. 2, the motion transformer 48 converts the oscillatory motion of member 62 to unidirectional rotary motion. The transformer comprises the ratchet wheel 28 which is rotatively mounted on a shaft 110 whose ends are secured in tabs 56 and 58. Shaft 110 is parallel to spring 64 and is located directly in front of that spring. The ratchet wheel is made of a suitable, impact-resistant plastic such as Delrin polyacetal and has a large number (e.g. 96) of small teeth 28a and it is perforated to minimize its weight. A driving pawl 112 is affixed to member 62 and arranged to engage teeth 28a. Driving pawl 112 is basically a relatively long, flat, spring-like member which is secured to the end face 76b of member portion 76 by screws 114 or other suitable means. The free end of pawl 112 rides on teeth 28a. That end is notched at 112a (FIG. 5) with the teeth engaging the bottom of the notch so that the pawl cannot be displaced sideways and become disengaged from teeth 28a when the device is subjected to shock.

The angle of face 76b, the pitch of teeth 28a and the arrangement of the ratchet wheel and oscillator member are designed so that when the member is at rest, the end of pawl 112 lies approximately half-way along one of the teeth 28a. Then, as the oscillator undergoes a full excursion in the clockwise direction, the pawl is carried beyond the end of that tooth. Then, when the oscillator commences counterclockwise rotation, the pawl engages that tooth and applies a force which is substantially tangential to the ratchet wheel. The pawl turns the wheel in the counterclockwise direction a sufficient distance to enable the pawl to engage behind the next tooth upon the second clockwise excursion of the oscillator member 62.

A second, spring-like retaining pawl 118 similar in construction to pawl 112 prevents backup of the ratchet wheel as the driving pawl is retracted to engage the next tooth. One end of the retaining pawl 118 is secured to plate 22 by suitable means such as screws 122. The free end of the pawl 118 is also notched at 118a and engages the ratchet wheel beyond the point at which pawl 112 engages that wheel. The retaining pawl is oriented so that when the oscillator and ratchet

wheel are at rest, its notched end 118a just butts against the rear face of a tooth 28a.

When member 62 oscillates, ratchet wheel 28 moves in the counterclockwise direction at a relatively rapid rate dependent upon the oscillator frequency. The bench mark 32 is painted or molded on the rim of the wheel so that one can easily observe the wheel in motion through slot 26.

As best seen in FIGS. 3 and 5, a pinion gear 124 integral with wheel 28 couples the rotary motion of the wheel to the gear reduction stage 52. Stage 52 comprises a train of spur gears rotatively mounted alternately on torsion spring 24 and shaft 110. A first gear 126 is mounted on the torsion spring and driven by the gear 124 affixed to the ratchet wheel. Gear 126 includes an integral follower 128 which drives a second similar gear 132 mounted on shaft 110. Gear 132 also includes an integrally formed, coaxial follower 134 which drives a third gear 136 of similar design mounted on torsion spring 24. Actually, the first two reduction gears 126-128 and 132-134 are identical, while the third reduction gear 136-138 has a slightly different gear ratio.

The follower 138 meshes with a specially designed gear 142 mounted on shaft 110 shown specifically in FIG. 4. The side of gear 142 facing the counter section 54 is formed with a pair of bosses 144 which project up toward the torsion rod 24 spring 64. This gear is designed this way so that a conventional off-the-shelf counter 54 can be used in the mechanism. In other words, counter 54 is composed of standard counter wheels 54a-54f. These wheels are all mounted on shaft 110. The counter also includes the usual pinion gears 152a-152f to couple motion between the individual wheels. These gears are all mounted on torsion spring 64. Also, conventionally, the first or least significant counter wheel 54a is turned by the first pinion gear 152a. Therefore, gear 142 is designed so that a boss 144 engages successive teeth of gear 152a during successive revolutions. In other words, for each revolution of gear 142, pinion gear 152a advances one tooth.

The illustrated mechanism is designed to indicate elapsed time in hours. Therefore, the gear ratios of the various gears in the gear reduction stage are arranged so that 1 hour's operation of the oscillator will cause the least significant counter wheel 152a to advance one digit.

In this embodiment all of the moving components of the mechanism are mounted on torsion spring 64 and shaft 110. This enables the mechanism to be contained in a small, compact package; also, it facilitates its assembly. We should mention, in addition, that the gears of the reduction stage and counter section which are mounted on the torsion spring are very lightweight and tend to float on the spring so that they have minimal effect on its twisting movements as member 62 oscillates.

The components of the timing mechanism are all assembled on base plate 22. Window 16 is then seated in a circular groove 150 (FIG. 2) at the rear of the bezel and sealed by epoxy resin or other suitable bonding agent. Then, the bezel is bonded to the front of base plate 22 with a similar bonding agent. Finally, the casing 12 is bonded to the bezel and base plate. The edge of the casing is provided with a circular lip 152 which seats in the circular groove 154 at the rear of the bezel. The casing also has a circular flange 156 spaced from lip 152 which seats in a groove 158 in the rear of flange

38. A bonding agent is applied to the surfaces of these mating parts so that the entire unit is sealed to keep out dust, dirt and moisture. The unit so packaged can withstand shocks as great as 1000 g's and more. The housing itself contributes some of this shock resistance. Also, the tabs 56 and 58 which support the elements of the timing mechanism are somewhat resilient and further isolate the parts from external forces.

As soon as current is applied to terminals 99a and 99b, member 62 commences to oscillate with the amplitude of oscillation rapidly reaching the point where the driving pawl 112 begins to index the ratchet wheel 28. As noted above, the end of the driving pawl is resting approximately half-way along one of the teeth of the ratchet wheel so there is essentially no load on member 62 when current is applied. Therefore, the member can accelerate rapidly and reach its maximum amplitude of oscillation in a fraction of a second.

For best operation of the timing mechanism, the current pulses applied to the drive coils 88 and 92 should be timed so that they are centered on, or symmetrical with, the output load pulse (i.e. at the instant when member 62 through its pawl 112 is advancing the ratchet wheel 28). Thus, the driving pulses are applied at just the instant when member 62 is under maximum load.

For illustrative purposes, we have shown the oscillator and ratchet wheel as driving a counter. However, it is obvious that the same arrangement could be used to turn other rotary members. For example, the ratchet wheel can be geared to a disk having openings at various points in its surface. When the disk is positioned between a light source and a photodetector, the arrangement of holes will permit light to be transmitted to the photodetector only at selected time intervals. The output of the detector can then control any conventional device operated on a time basis. For example, the device may take samples of the atmosphere periodically, etc. In a different application, the rotating member may be a polygonal mirror positioned in the path of a beam of light. Rotation of the mirror would then cause a light beam to scan successively across a surface. Then, by suitably modulating the light beam, information could be displayed on that surface.

The present timing mechanism can also be powered by an alternating current supply. In this event, the natural frequency of the oscillatory body is set to the frequency of the supply current and the supply voltage is applied directly to the electromagnet terminals. Thus, the oscillator is slaved to the supply current frequency at typical variations in that frequency of at least ± 2 percent of the natural frequency of the oscillator. Of course, in this event, the phase sensing coil and associated electronics are not required. Consequently, this mechanism used as an AC timer can be made less expensively than one which runs on direct current.

FIGS. 6 to 8 illustrate another embodiment of the timing mechanism which is preferable when the torque needs to the ratchet wheel are relatively high due to oscillator windage, hysteresis losses and the like. Also, this embodiment has an added advantage in that there is improved decoupling of the oscillator and base, with the result that the oscillator operates at a relatively high amplitude with low power input. As a consequence, the mechanism has a shorter start-up time and superior accuracy.

This embodiment of the invention is similar in many respects to the FIGS. 1 to 5 embodiment. Consequently, for purposes of this description, we will dwell only on the main differences from the first embodiment.

This version of the mechanism has a base 202. The elements of the mechanism are mounted on three parallel tabs 204, 206 and 208 affixed to base 202. Tab 204 is supported on two pedestals 209a and 209b projecting out from the base and is situated near the middle of the base (FIG. 7). Tabs 206 and 208 are connected directly to the base and are spaced on opposite sides of tab 204. The mechanical oscillator shown generally at 210 is comprised of a relatively long and stiff torsion spring 212 which is secured at its midpoint to tab 204 approximately midway along the length of the tab. Spring 212 has a raised portion 212a at its point of attachment to tab 204 to provide a stronger point of engagement with the tab and to minimize stresses developed at the joint between the two.

A rotary oscillatory body 214 is secured at its center of mass to one end of spring 212. Also, a second oscillatory member 216 is secured at its center of mass to the opposite end of spring 212. Each oscillatory body has a relatively large mass which is located away from its center of mass giving the body a relatively high moment of inertia. Body 214 consists of a relatively long, flat, generally rectangular plate. Member 216, on the other hand, is more or less discoid in shape.

When body 214 is displaced angularly, it tends to oscillate about the axis of spring 212. Also, the other oscillatory member 216 oscillates about the same axis in sympathy. The system is arranged so that both oscillatory members have substantially the same natural frequency of oscillation. With this arrangement, the member 216 exerts a counterbalancing influence which results in reduced vibration being transmitted to base 202 as the oscillator oscillates. In addition, this reduced damping increases the efficiency of the oscillator and the accuracy of the timing mechanism as a whole.

A discoid permanent magnet 220 is mounted at one end of body 214. The end of the body is notched at 214a so that the magnet is actually recessed into the body. The oscillatory body also has a relatively long leg 214b located on the opposite side of the center of rotation of the body and extending toward the base to compensate for the added mass on the body due to magnet 220. A single driving coil 220 is supported by a tab 224 connected to pedestal 209a (FIG. 7). Coil 222 is positioned directly opposite the magnet 220 and, when pulsed, tends to repel the magnet, causing the body 214 to rotate about its axis (i.e. spring 212). A printed circuit board 226 is supported by a pair of slotted pedestals 227a and 227b above the spring 212 (FIG. 7). Board 226 carries a suitable electronic circuit to apply current pulses to coil 222 at the proper time to maintain body 214 in oscillation as described above.

As before, a phase sensing coil 228 is provided adjacent coil 222. Each time magnet 220 approaches the center point of its clockwise rotation (FIG. 6), a current is induced in coil 228 which is amplified and applied to energize the drive coil 222 in the manner described above.

A ratchet wheel 232 is rotatively mounted on a shaft 234 whose ends are secured to tabs 206 and 208 so that the shaft is positioned directly in front of the torsion spring 212. Also a spring-like pawl 236 is secured at

one end by screws 238 or other suitable means to the forward edge of body 214 adjacent magnet 220. The free end 236a of the pawl is arranged to engage the teeth of ratchet wheel 232 as described above in connection with FIGS. 2-5. When body 214 oscillates, the pawl 236 advances the ratchet wheel in the counterclockwise direction in FIG. 6. A retaining pawl 240 which is secured at one end to base 202 and whose other end engages the ratchet wheel teeth prevents the wheel from moving in the clockwise direction as the driving pawl 236 is retracted.

The ratchet wheel 232 carries a pinion gear 244 which couples the rotary motion of the ratchet wheel to a gear reduction stage shown generally at 246. The stage 246 is basically the same as the one disclosed in FIGS. 3 and 5, except that the gears are not mounted on the same shafts which support the ratchet wheel and oscillator body. Rather, the first reduction gear 248 is mounted on a shaft 249 (FIG. 6) which is supported by tabs 206 and 208 directly below the ratchet wheel shaft 234. This gear meshes with the pinion of the second reduction gear 252 which is rotatively supported by shaft 253. This shaft is supported by tabs 206 and 208 directly behind shaft 249. The tab 204 is recessed at 204a to accommodate the shaft (FIG. 6). The pinion of this gear meshes with the third reduction gear 254 also mounted on shaft 249. Gear 254 is similar to gear 142 in that it is specially adapted to drive the pinion 256a of a conventional counter 256 (FIG. 8). This counter 256 is identical to counter 54 in FIG. 5 and will not be further detailed here. Suffice it to say that the counter wheels of counter 256 are all mounted on shaft 249 while the associated pinion gears are supported by shaft 253. Otherwise the counter operates in exactly the same way as counter 54, indicating the elapsed time through a window 260 in base 202.

When drive coil 222 is energized, body 214 oscillates about the axis of spring 212 turning the ratchet wheel 232 in the counterclockwise direction and, hence, incrementing the counter 256 at a controlled rate. We should mention at this point that a recess 214a is provided in body 214 to provide clearance for shaft 253 when body 214 oscillates. Also body 216 is notched at 216a (FIG. 7) for the same reason. This embodiment of the invention has minimal energy losses and a relatively high mechanical Q. Also, it is relatively independent of externally applied vibration and shock forces. Consequently, it is especially suitable as a clock or elapsed time indicator destined for use in an environment where these forces are present.

Actually, the present system is accurate enough and so inexpensive to make that it can be used as a substitute for present-day batter-operated wall clocks and automobile clocks. Since the frequency of oscillator 46 is quite constant and relatively temperature independent, the time indication is much more accurate than that provided by present-day inexpensive d.c. operated clocks.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes can be made in the above construction without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described.

I claim:

1. A timing mechanism comprising
 - A. a base,
 - B. a body
 - C. means for rotatively mounting the body at its center of mass to the base,
 - D. means for biasing the body so that it tends to assume a neutral position about its axis of rotation said body having a moment of inertia which is high enough such that when the body is deflected from this neutral position it tends to oscillate about its axis at its own natural frequency for a prolonged period of time, and
 - E. magnetic means for applying an off-axis force to the body periodically so as to excite the body to and maintain it in oscillation about its axis.
2. The timing mechanism defined in claim 1 wherein the biasing means includes a torsion spring connected between the base and the center of rotation of the body.
3. The timing mechanism defined in claim 2 wherein
 - A. one end of the torsion spring is secured to the base, and
 - B. the body is secured near the free end of the spring.
4. The timing mechanism defined in claim 3 and further including restraining means for preventing the free end of the torsion spring from vibrating off the spring axis
5. The timing mechanism defined in claim 2
 - A. wherein
 1. a midportion of the torsion spring is secured to the base, and
 2. the body is mounted adjacent one end of the torsion spring, and
 - B. further including a second body having a center of mass secured at said center adjacent the other end of the torsion spring, said second body tending to oscillate sympathetically with the other body.
6. The timing mechanism defined in claim 1 wherein the magnetic means comprise
 - A. a ferromagnetic structure affixed to the body near the rim thereof,
 - B. means supported by the base for generating a pulsed electromagnetic field adjacent the ferromagnetic structure for producing the force which opposes the biasing means, the frequency of the field pulses being related to the natural oscillation frequency of the body.
7. The timing mechanism defined in claim 6 and further including
 - A. means for sensing the phase of the oscillating body and producing an output signal in response thereto, and
 - B. means responsive to the output signal for exciting the field producing means.
8. The timing mechanism defined in claim 7 wherein
 - A. the phase sensing means is a wire coil in which a current is induced when the coil and ferromagnetic structure are in close proximity and there is relative movement between the two,
 - B. the exciting means is comprised of an amplifier which amplifies the current signal from the phase sensing coil, and

- C. the field producing means includes a wire coil which receives the amplified current signal from the amplifying means and generates a magnetic field in response thereto.
9. The timing mechanism defined in claim 1 and further including
 - A. a rotary member supported by the base, and
 - B. a motion transformer for converting the oscillatory motion of the body to unidirectional motion of the rotary member.
10. The timing mechanism defined in claim 1 and further including
 - A. a ratchet wheel rotatively supported by the base in close proximity to the oscillatory body, and
 - B. a pawl secured to the body and in operative engagement with the teeth of the ratchet wheel for advancing the wheel when the body oscillates.
11. The timing mechanism defined in claim 10 and further including means for preventing rotation of the ratchet wheel in the direction opposite to the direction in which it is driven by the pawl.
12. The timing mechanism defined in claim 9 and further including
 - A. one or more counter wheels rotatively supported by the base, and
 - B. means for coupling the rotary motion of the rotary member to a counter wheel.
13. The timing mechanism defined in claim 12 wherein
 - A. The biasing means is a torsion spring which also supports the body, and
 - B. the counter wheels are rotatively mounted on the torsion spring.
14. The timing mechanism defined in claim 12 wherein the coupling means include one or more gears operating between the rotary member and the counter wheels so that a selected number of rotations of the rotary member produce a different selected number of rotations of the wheel.
15. A timing mechanism comprising
 - A. a base,
 - B. a body having a center of mass,
 - C. a torsion spring connected at one point on its length to the base and at a second point on its length to the body at its center of mass so that when the body is rotated about its center, the spring winds up and exerts a restoring bias on the body, with the result that the body has a selected natural frequency of oscillation
 - D. a magnet mounted on the body near its rim,
 - E. a second magnet supported by the base so that it is opposite the first magnet, at least one of the magnets being an electromagnet,
 - F. means for energizing the electromagnet periodically when the body is oriented at a selected angular position about its center of rotation so that the body is maintained in oscillation.
16. The timing mechanism defined in claim 15 and including
 - A. an additional magnet mounted on the body near its rim, said additional magnet being symmetrically disposed about the center of mass of the body with respect to the first magnet, and
 - B. a fourth magnet supported by the base opposite the third magnet, at least one of the third and fourth magnets being a second electromagnet, said second electromagnet operating in coincidence

with the other electromagnet to help maintain the body in oscillation.

17. The timing mechanism defined in claim 15

A. wherein,

1. the torsion spring is supported near its mid-point by the base, and
2. further including a second body supported at its center of mass adjacent the other end of the torsion spring so that it oscillates sympathetically with the other body.

18. The timing mechanism defined in claim 17 wherein the natural frequencies of oscillation of the two bodies are comparable.

19. The timing mechanism defined in claim 15 and further including means operatively associated with one of the oscillatory bodies for controlling the time of occurrence of an event.

20. The timing mechanism defined in claim 15 and further including

- A. a ratchet wheel located relatively near the body and arranged so that its faces are in planes lying parallel to the plane of rotation of the body,
- B. a flexible resilient driving pawl secured to the body, said pawl having an edge arranged to engage the teeth of the ratchet wheel so as to turn the wheel in a given direction when the body oscillates, and
- C. means for preventing the wheel from turning in the direction opposite to the given direction.

21. The timing mechanism defined in claim 20 wherein

- A. said edge of the pawl is notched, and
- B. the ratchet wheel teeth engage the bottom of the notch.

22. The timing mechanism defined in claim 20 wherein the opposite rotation preventing means include a retaining pawl supported by the base and having an edge engaging the ratchet wheel teeth when the driving pawl is retracted by the oscillatory body.

23. The timing mechanism defined in claim 22 and further including

- A. means defining a window in the base adjacent the rim of the ratchet wheel, and
- B. indicia on the ratchet wheel rim which appears in the window periodically as the ratchet wheel rotates.

24. The timing mechanism defined in claim 20 wherein the edge of the driving pawl moves tangentially to the ratchet wheel when it advances the wheel in the given direction as the body oscillates.

25. The timing mechanism defined in claim 20 and further

- A. including a counter supported by the base, and
- B. means driven by the ratchet wheel for incrementing the counter.

26. The timing mechanism defined in claim 25 and further including

- A. a window in the base adjacent the counter through which the numerals on the counter are apparent,
- B. a casing enclosing all of the recited timing mechanism components, and
- C. means for securing the casing to the base.

27. The timing mechanism defined in claim 25 wherein the driven means include reduction gears.

28. The timing mechanism defined in claim 15 wherein the energizing means include

A. a sensing coil supported on one of the base and the body in which a current signal is induced when it is in close moving proximity to the magnet on the other of the base and the body, and

B. a switch responsive to the current signal in the sensing coil for controlling the energization of the electromagnet so that the body is pulsed magnetically at a controlled rate dependent primarily on the natural oscillation frequency of the body.

29. The timing mechanism defined in claim 28 wherein the energizing means also include an amplifier for amplifying the current signal in the sensing coil prior to its application to the switch.

30. The timing mechanism defined in claim 28 wherein the electromagnet is pulsed as the body is advancing the ratchet wheel in the given direction.

31. A timing mechanism comprising

- A. a base,
- B. a torsion spring,
- C. means for securing the torsion spring near its mid-point to the base,
- D. a body secured at its center of mass adjacent one end of the torsion spring, said body tending to oscillate about its center of mass at a selected natural frequency,
- E. a second body secured at its center of mass adjacent the opposite end of the torsion spring, said second body tending to oscillate sympathetically with the first body at a selected natural frequency,
- F. a first magnet secured to one of the bodies near its rim,
- G. a second magnet supported by the base near the first magnet, at least one of said magnets being an electromagnet,
- H. means for energizing the electromagnet so that it reacts with the other magnet and tends to angularly deflect the attached body about its center of mass,
- I. means for controlling the energizing of the electromagnet so that the electromagnet is pulsed momentarily when the body is at a selected angular position about its center of mass so as to maintain the body in oscillation, said controlling means including
 1. a phase sensing coil in which signal is induced when the coil is in close moving proximity with a magnet, and
 2. a switch responsive to the current signal for controlling the power applied to the electromagnet,
- J. a ratchet wheel rotatively supported by the base in close proximity to the body,
- K. a pawl secured to the body and having an edge arranged to engage the teeth of the ratchet wheel and advance the wheel in a given direction when the body oscillates,
- L. A retaining pawl supported by the base and having an edge arranged to engage the ratchet wheel teeth to prevent the wheel from moving in a direction opposite to the given direction,
- M. a counter supported by the base,
- N. reduction gears driven by the ratchet wheel for incrementing the counter at a controlled rate as the body oscillates,
- O. a window in the base adjacent the counter through which the numbers displayed by the counter may be observed,
- P. A housing protectively enclosing the moving components of the timing mechanism, said housing being secured to the base, and
- Q. means on the outside of the housing for conducting an electrical current to the electromagnet inside the housing.