Oct. 9, 1962 M. HETZEL 3,057,147

MOTION CONVERTER

Filed July 30, 1956 2 Sheets-Sheet 1

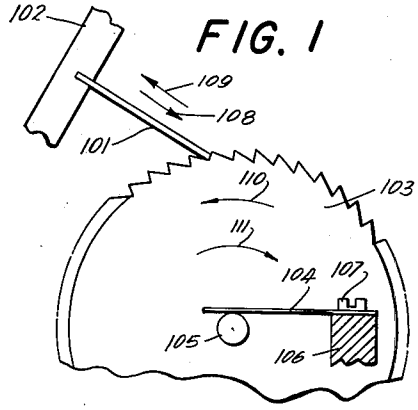

FIG. 1

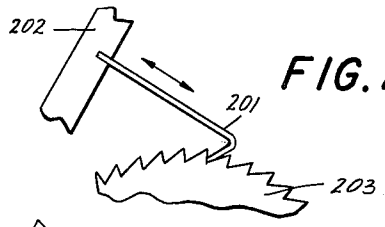

FIG. 2

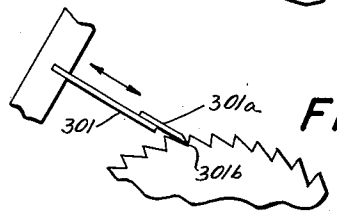

FIG. 3

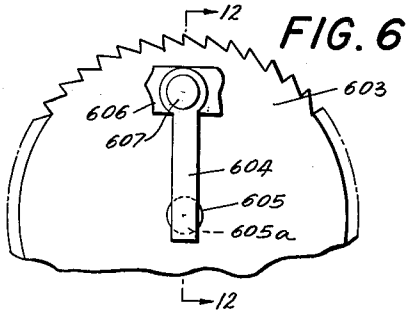

FIG. 6

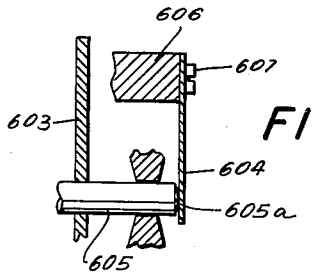

FIG. 7

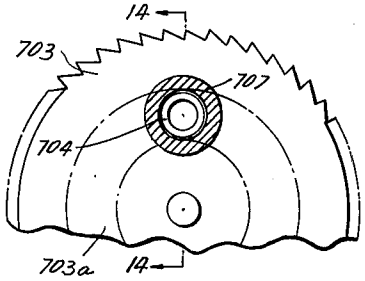

FIG. 8

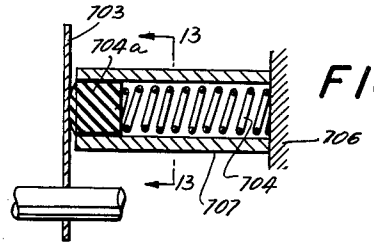

FIG. 9

FIG. 15

FIG. 13

FIG. 14

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MOTION CONVERTER

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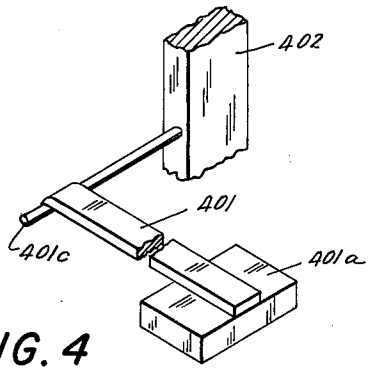

FIG. 4

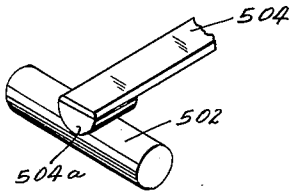

FIG. 5

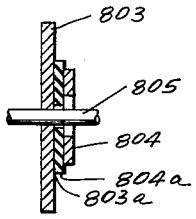

FIG. 11

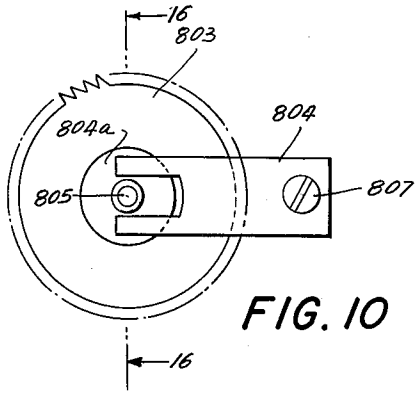

FIG. 10

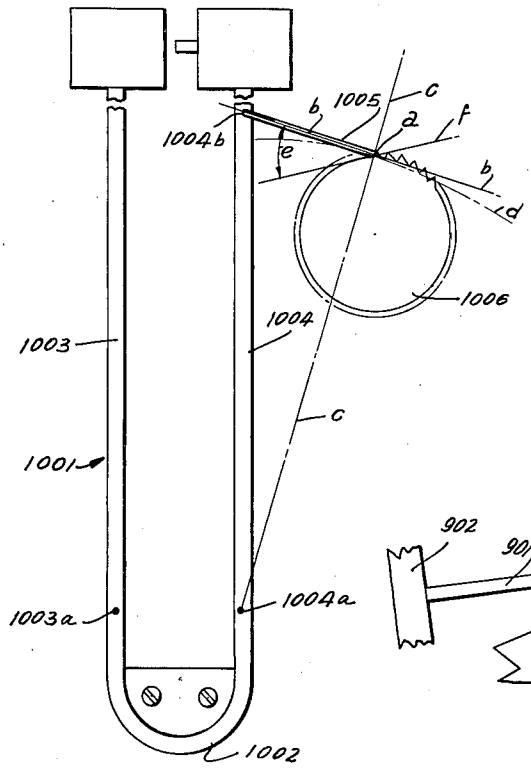

FIG. 16

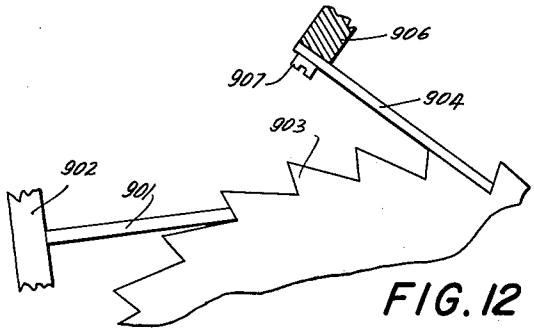

FIG. 12

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United States Patent Office

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3,057,147

MOTION CONVERTER

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Filed July 30, 1956, Ser. No. 600,922
12 Claims. (Cl. 58—23)

The present invention relates to a motion converter. More particularly, the present invention relates to a motion converter capable of converting the oscillatory movement of a mechanical vibrator into rotary movement. The motion converter may thus be used in a timepiece which includes a vibrator as well as suitable means for oscillating the same wherein the rotary movement obtained from the converter drives the timepiece mechanism. The timepiece may be of the type disclosed in copending applications Serial No. 436,949 filed June 15, 1954, now abandoned, Serial No. 485,781 filed February 2, 1955, now abandoned, Serial No. 547,510 filed November 17, 1955, now abandoned (said application Serial No. 547,510 being a continuation of application Serial No. 463,462 filed October 20, 1954, now abandoned), Serial No. 565,451 filed February 14, 1956, now Patent No. 2,888,582, May 26, 1959, Serial No. 565,452 filed February 14, 1956, now Patent No. 2,949,727, Aug. 23, 1960, Serial No. 570,958 filed March 12, 1956, Serial No. 580,813 filed April 26, 1956, now Patent No. 2,908,174, Oct. 13, 1959, Serial No. 584,709 filed May 14,. 1956, now Patent No. 2,960,817, Nov. 22, 1960 and Serial No. 588,409 filed May 31, 1956, now Patent No. 2,900,786.

The above-mentioned copending applications concern themselves with an electric timepiece which incorporates suitable electrical means for oscillating a mechanical vibrator, the latter preferably being in the form of a tuning-fork type vibrator. A reciprocatable drive element, such as a pawl, is attached to one of the tines of the vibrator and cooperates with a ratchet wheel so as to cause rotation thereof during oscillation of the tines. The pawl reciprocates with a stroke the length of which is dependent upon the amplitude of oscillation of the tines, and the electrical means for oscillating the tines are capable of normally maintaining the amplitude of oscillation of the tines within a range wherein the stroke of reciprocation of the pawl, in a direction substantially tangent to the ratchet wheel at the point of contact or engagement between the pawl and the ratchet wheel, is at least as great as the pitch of the ratchet teeth but is not greater than twice this pitch. In this way, each oscillation of the tines causes the ratchet wheel to be rotated throughout an angular distance which corresponds to the pitch of the ratchet teeth. Thus, the rotational speed of the ratchet wheel is exactly proportional to the frequency of oscillation of the tines, and since the latter may be maintained constant with an extremely high degree of accuracy, the rotational speed of the ratchet wheel and of the timepiece mechanism, which it drives is similarly maintained constant with the same high degree of accuracy.

In practice, the pawl or other drive element includes a leaf spring which is attached at one of its ends to one of the tines of the vibrator and which at its other end, either directly or through the intermediary of an engaging element, contacts the ratchet teeth, so that when the pawl moves forwardly in one direction, it engages the ratchet wheel positively and causes the same to rotate in one angular direction, whereas when the pawl moves backwardly in the opposite direction it engages the ratchet wheel frictionally and causes, or at least tends to cause, the same to rotate in the opposite angular direction. It will be understood that if the pawl were permitted so to rotate the ratchet wheel in this opposite direction, the

pawl might not, upon completing its backward stroke, come into engagement with the next ratchet tooth. Instead, the pawl might remain in engagement with the same tooth so that each reciprocation of the pawl would not necessarily result in the proper angular displacement of the ratchet wheel, thereby adversely affecting the accuracy of the timepiece.

Moreover, once the pawl has completed its forward movement and commenced its backward movement, the ratchet wheel, although no longer subject to the driving action of the pawl, will tend to continue it rotation simply under the influence of its own inertia or momentum, as well as that of the timepiece mechanism which the ratchet wheel drives. If this were permitted to occur, successive reciprocations of the pawl would not necessarily find the same in engagement with successive ratchet teeth, thereby again adversely affecting the accuracy of the timepiece.

It is therefore an object of the present invention to overcome the above disadvantages.

It is another object of the present invention to provide an electric timepiece incorporating a motion converter capable of converting the oscillatory movement of a mechanical vibrator into the rotary movement of a timepiece mechanism wherein undesired rotation of the timepiece mechanism, i.e., rotation other than forward rotation under the influence of anything other than the vibrator, is prevented.

It is yet another object of the present invention to provide a motion converter capable of converting the oscillatory movement of a mechanical vibrator into the rotary movement of a timepiece mechanism wherein the speed of rotation of the timepiece mechanism is maintained exactly proportional to the frequency of oscillation of the vibrator.

It is a still further object of the present invention to provide a motion converter capable of converting mechanical oscillations into rotary movement wherein the rotational speed produced is exactly proportional to frequency of the mechanical oscillations.

It is a still further object of the present invention to provide a motion converter capable of transforming the oscillatory motion of a vibrator into rotary motion wherein the transformation takes place with maximum efficiency.

The objects of the present invention further include the provision of an extremely accurate timepiece which may readily be mass-produced at low cost.

With the above objects in view, the present invention mainly resides in that improvement in a timepiece incorporating a timepiece mechanism which includes a base, a timepiece mechanism actuator rotatably mounted on the base and operatively associated with the timepiece mechanism for actuating the same during rotation of the actuator in one angular direction, reciprocatable driving means for driving the actuator and cooperating therewith in such a manner that when the driving means moves in one direction it engages the actuator and causes the same to rotate in this one angular direction, and means for limiting rotation of the actuator to rotation in this one angular direction. Preferably, the last mentioned means limit rotation of the actuator to rotation in this one angular direction by the driving means during periods while the same is in motion-transmitting engagement with the actuators and also prevent rotation of the actuator in the opposite angular direction.

According to the preferred embodiment of the present invention, the acuator is a ratchet wheel and the driving means is a pawl, the latter cooperating with the former in such a manner that when the pawl moves forwardly in one direction, it engages the ratchet wheel positively and causes the same to rotate in the one angular direction. When the pawl moves backwardly in the opposite

direction, it engages the ratchet wheel frictionally and causes the same to rotate in the opposite angular direction. Brake means are provided which frictionally engage the ratchet wheel with a braking force which is sufficiently great to prevent rotation of the ratchet wheel in this opposite angular direction during backward movement of the pawl and which braking force is also sufficiently great to prevent rotation of the ratchet wheel in the one angular direction under the influence of its inertia after the pawl has completed its forward movement and commenced its backward movement.

According to a preferred embodiment of the present invention the pawl is connected to a mechanical vibrator which is carried by the base and is oscillatable relative thereto about an axis of oscillation. The pawl is attached to the vibrator at a point thereof that lies on a line which passes through the point of engagement between the pawl and the ratchet wheel and is normal to a line passing through this point of engagement and through the axis of oscillation. In this way, the pawl reciprocates along a path which passes through the point of engagement between the pawl and the ratchet wheel, which path is substantially tangent to a circle having its center at the axis of oscillation and passing through this point of engagement.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings in which:

FIG. 1 is a fragmentary view, partly in section, of one embodiment of a motion converter according to the present invention;

FIG. 2 is a fragmentary view of a motion converter according to the present invention incorporating a modified pawl;

FIG. 3 is a fragmeentary view of a motion converter according to the present invention incorporating another modified pawl;

FIG. 4 is a fragmentary perspective view of yet another pawl adapted to be used in a motion converter according to the present invention, the figure further showing a mounting arrangement by which the pawl can be secured to the tine of a tuning-fork type vibrator;

FIG. 5 is a fragmentary perspective view of a modified friction brake adapted to be used in a motion converter according to the present invention;

FIG. 6 is a diagrammatic view of another modified friction brake adapted to be used in a motion converter according to the present invention;

FIG. 7 is a sectional view taken along line **12—12** of FIG. 11;

FIG. 8 is a diagrammatic view of yet another modified friction brake adapted to be used in a motion converter according to the present invention, the view being taken along line **13—13** of FIG. 14;

FIG. 9 is a sectional view taken along line **14—14** of FIG. 13;

FIG. 10 is a diagrammatic view of a still further modified friction brake adapted to be used in a motion converter according to the present invention;

FIG. 11 is a sectional view taken along line **16—16** of FIG. 15;

FIG. 12 is a fragmentary view, partly in section, of yet another embodiment of a motion converter according to the present invention;

FIG. 13, 14 and 15 show different types of ratchet teeth shapes which the ratchet wheel may have; and

FIG. 16 is a diagrammatic illustration of another feature of the present invention.

The oscillations of the tuning fork must, in order to be useful in a timepiece of the type described, be converted into a rotary movement. This conversion can take place by the transmission or motion converter mechanism illustrated in FIG. 1.

The motion converter includes, a pawl constituted by a leaf spring **101** which is attached at one end thereof to the vibrator **102** (one tine of the tuning fork) and which engages at its other end the ratchet wheel **103**, there being no separate tooth. The braking means, is constituted by a second leaf spring **104** one end of which is frictional engagement with an outer peripheral friction surface of a shaft **105** which is rotatable with the ratchet wheel **103**. The leaf spring **104** is secured at its other end to a member **106** of the timepiece base plate by means of a screw **107**, and is arranged in a plane substantially normal to the plane of rotation of the ratchet wheel so that the pressure exerted by the free end of the leaf spring **104** is substantially perpendicular to the axis about which the ratchet wheel **103** and the shaft **105** rotate.

It will readily be seen from this figure that during forward movement of the pawl in the direction of the arrow **108**, it is in positive motion-transmitting engagement with the ratchet wheel, whereas during backward movement in the direction of the arrow **109**, the pawl is in frictional engagement with the face of the particular ratchet tooth with which the pawl is in engagement. As set forth above, backward rotation of the ratchet wheel in the direction of the arrow **110** is prevented by the leaf spring **104**, as is forward rotation in the direction of the arrow **111** due to inertia after the pawl has completed its forward and commenced its backward movement.

While the leaf spring **101** in the embodiment shown in FIG. 1 cooperates with the ratchet wheel in such manner that during each forward stroke of the pawl the vibrator, through the intermediary of this leaf spring, exerts a pushing force upon the particular ratchet tooth with which the leaf spring is in engagement, the leaf spring **201** shown in the embodiment of FIG. 2 has a hooked free end so that the vibrator **202** exerts a pulling force on the teeth of the ratchet wheel **203**.

In the embodiment shown in FIG. 3 the leaf spring **301** carries at its free end a separate engaging element or tooth **301***a* which, as set forth above, may be a precious jewel. The tooth may be wider than the leaf spring and project ahead of the latter, and be formed with a relative sharp edge **301***b*. If desired, a tooth of this type may be incorporated in a pawl device wherein the leaf spring has a hooked free end, as is shown in FIG. 2.

The embodiment shown in FIG. 4 differs from the above-described one in that the engaging tooth **401***a* carried by the leaf spring **401** is substantially block-shaped. Also, FIG. 4 shows how the leaf spring may be attached to the vibrator **402**, the latter being formed with a relatively shallow bore which does not extend more than about one quarter of the way through the tine of the vibrator. The leaf spring **401** is soldered or otherwise attached to a mounting pin **401***c* and this pin is inserted into the bore of the tine.

FIG. 5 is a fragmentary perspective of another embodiment of a friction brake arrangement according to the present invention. It differs from that shown in FIG. 1 in that the brake leaf spring **504** carries an engaging element **504***a* which frictionally engages an outer peripheral friction surface of the shaft **502** with which the ratchet wheel (not shown) rotates. The engaging element has an engaging surface which is curved about an axis transverse to the axis about which the shaft **502** rotates so that this engaging surface is in point contact frictional engagement with the shaft.

In the embodiment shown in FIGS. 6 and 7 the ratchet wheel **603** rotates with a shaft **605** which has a free end face **605***a*. The latter is frictionally engaged by the free end of the leaf spring **604** which at its other end is attached to a member **606** of the timepiece base plate by means of a screw **607**. Thus, the instant embodiment

differs from the braking means shown above in that the leaf spring acting as the braking element does so on an end face of the shaft instead of a peripheral surface thereof.

FIGS. 8 and 9 show an embodiment of a friction brake arrangement wherein the ratchet wheel **703** is so shaped as to have an annular friction surface portion **703***a* shown in dot-and-dash lines in FIG. 8. This friction surface portion may simply be part of one of the faces of the ratchet wheel **703** and thus lies in a plane transverse to the axis about which the ratchet wheel rotates. The annular frictional surface is engaged by an engaging element or plunger **704***a* which is slidably arranged within a tubular guide element **707**. The latter extends in a direction normal to the annular friction surface and is secured to a member **706** of the timepiece base plate. A compression spring **704** is interposed between the plunger **704***a* and the member **706** and constantly urges the plunger into frictional engagement with the annular friction surface portion **703***a*.

In the embodiment shown in FIGS. 10 and 11, the ratchet wheel **803** rotates together with a shaft **805** and, as in the above described embodiment, is so shaped as to have an annular friction surface portion **803***a* which may simply be part of the one of the ratchet wheel faces. An annular engaging element **804***a* encompasses the shaft **805**, is freely rotatable relative thereto and is arranged adjacent the ratchet wheel **803**. The engaging element **804***a* is pressed into face-to-face contact and thus into frictional engagement with the friction surface portion **803***a* by a leaf spring **804**, the latter being formed with a bifurcated free end portion the arms of which engage the element **804***a* on diametrically opposite points relative to the shaft **805**. The leaf spring **804** is attached at its other end to the timepiece base plate by means of a screw **807**.

In the embodiment shown in FIG. 12, the ratchet wheel **903** which is driven by a pawl leaf spring **901** attached to the vibrator **902**, cooperates with a second leaf spring **904** attached at one end to a member **906** of the timepiece base plate by means of a screw **907**. The leaf spring **904** is not only in friction engagement with the particular tooth with which it is in contact, but also acts as a pawl for preventing backward rotation of the ratchet wheel.

In any of the above-described embodiments the teeth of the ratchet wheel may have any suitable configuration. For example, the teeth may have the rip-saw tooth configuration shown in FIG. 13, the V-shaped configuration shown in FIG. 14, or the undulatory configuration shown in FIG. 15.

FIG. 16 is a diagrammatic illustration of another feature of the present invention which incorporates a vibrator **1001**. The same may be of the tuning-fork type having a base portion **1002** and a pair of tines **1003** and **1004** which may be vibrated in any suitable manner. The vibration of each of the tines is in the nature of an arcuate oscillation about a corresponding nodal point in the stem of the fork, which point may be termed an axis of oscillation, the same being shown at **1003***a* and **1004***a*, respectively. The tine **1004** carries a pawl **1005** cooperating with a ratchet wheel **1006** which is rotatable about an axis of rotation normal to the plane within which the tines **1003** and **1004** oscillate. The pawl **1005** engages the ratchet wheel **1006** at a point *a* so as to rotate the same during oscillation of the tine **1004**, and is attached to the tine **1004** at an attachment point **1004***b*, this point being so selected that it lies in a line *b* which passes through the point *a* and which is normal to a second line *c* that passes through the point *a* and through the axis of oscillation **1004***a* of the tine **1004**. Thus, when the tine **1004** is oscillated, the pawl **1005** is reciprocated along a path which passes through the point of engagement *a* and which is tangent to a circle *d* having its center at the axis of oscillation **1004***a* and passing through the point *a*.

By virtue of the above arrangement, the entire driving force of the vibrator, rather than merely a component thereof, is transmitted to the ratchet wheel **1006**, thus permitting the vibrator operate at maximum efficiency. This, in turn, reduces the power required to drive the vibrator so that even a very small battery can for very long periods supply the timepiece with the necessary energy.

It has been found that in order to insure proper positive engagement between the pawl and the ratchet wheel, the path along which the pawl reciprocates should be inclined to a line tangent to the ratchet wheel at the point of engagement between the pawl and the ratchet wheel. In the FIG. 16 the vibrator **1001** and ratchet wheel **1006** are shown as being so arranged relative to each other that the line *b*, which is the path along which the pawl **1005** reciprocates, forms an angle *e* with a line *f* tangent to the ratchet wheel at the point *a*. This angle *e* may be of the order of approximately 30°.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of motion converters differing from the types described above.

While the invention has been illustrated and described as embodied in an electric timepiece, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention. For example, the vibrator may have a configuration other than that illustrated in the instant application, and be shaped as is shown in copending application Serial No. 565,451. Also, the balance weight carried by one of the tines may be replaced by a magnetic drum similar to that carried by the other tine, in which event each magnetic drum cooperates with one of the two coils forming part of the electrical oscillating means, as disclosed in copending application Serial No. 570,958. Moreover, the abutment means which limit the maximum possible amplitude of oscillation may be constructed differently, for example, as disclosed in copending application Serial No. 570,958.

Still further, a timepiece incorporating a motion converter according to the present invention may be aranged as disclosed in copending application Serial No. 588,409.

Additionally, the exact construction of the braking means need not be limited to those shown in the above-described embodiments. For example, the leaf spring forming part of the brake may engage a separate friction wheel which rotates together with the ratchet wheel. Alternatively, such leaf spring may, without acting as a pawl, engage the crests of the ratchet teeth which together form a discontinuous outer peripheral friction surface. In this connection reference may be had to application Serial No. 463,462, now abandoned, and to copending applications Serial No. 547,510 and Serial No. 580,813.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention, and therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be secured by Letters Patent is:

1. In a timepiece having a timepiece mechanism, in combination, a base; ratchet wheel means rotatably mounted on said base and being operatively associated with said timepiece mechanism for actuating the same during rotation of said ratchet wheel means in one angular direction; pawl means for driving said ratchet wheel means and cooperating therewith in such a manner that

when said pawl means moves forwardly in one direction it engages said ratchet wheel means positively and causes the same to rotate in said one angular direction and that when said pawl means moves backwardly in the opposite direction it engages said ratchet wheel means frictionally and tends to cause the same to rotate in the opposite angular direction; a tuning fork vibrator carried by said base and having a tine connected to said pawl means for reciprocating the same during oscillation of said tine; said tine, said pawl means and said ratchet wheel lying in the same plane and braking means frictionally engaging said ratchet wheel means with a braking force which is sufficiently great to prevent rotation of said ratchet wheel means in said opposite angular direction during backward movement of said pawl means, and which braking force is also sufficiently great to prevent rotation of said ratchet wheel means in said one angular direction under the influence of its inertia after said pawl means has completed its forward movement and commenced its backward movement, said tine vibrating about an axis of oscillation, said pawl being connected to said tine at a point which lies on a first line passing through the point of engagement with said ratchet wheel, which first line is normal to a second line extending from said point of engagement to said axis of oscillation, said ratchet wheel lying adjacent the upper end of said tine, the line extending through said pawl means and passing through said point of engagement forming with a line tangential to said ratchet wheel and also passing through said point of engagement an angle of about 30 degrees.

2. The combination defined in claim 1 wherein the natural frequency of said pawl means is at least twice as great as that of said vibrator.

3. The combination defined in claim 1 wherein said pawl means include a leaf spring attached at one end thereof to said vibrator and engaging at the other thereof said ratchet wheel means.

4. The combination defined in claim 1 wherein said ratchet wheel means is formed with an annular friction surface portion lying in a plane transverse to the axis about which said ratchet wheel means is rotatable, and wherein said braking means act in a direction normal to said annular friction surface portion and frictionally engage the same.

5. The combination defined in claim 4 wherein said braking means include an engaging element mounted for movement in said direction normal to said annular friction surface portion of said ratchet wheel means and a spring constantly urging said engaging element into frictional engagement with said annular friction surface portion.

6. The combination defined in claim 4 wherein said braking means include a tubular guide element which is carried by said base and which extends in a direction normal to said annular friction surface portion and is in alignment therewith, an engaging element slidably arranged within said tubular guide element and adjacent said annular friction surface portion, and a compression spring interposed between said engaging element and said base and constantly urging said engaging element into frictional engagement with said annular friction surface portion.

7. The combination defined in claim 4 wherein said braking means include an annular engaging element adjacent said annular friction surface portion of said ratchet wheel means, and spring means constantly urging said engaging element into face-to-face contact and thus into frictional engagement with said annular friction surface portion.

8. The combination defined in claim 1 wherein said ratchet wheel means is formed with ratchet teeth having a substantially rip-saw tooth configuration.

9. The combination defined in claim 1 wherein said ratchet wheel means is formed with ratchet teeth having a substantially V-shaped configuration.

10. The combination defined in claim 1 wherein said ratchet wheel means is formed with ratchet teeth having a substantially undulatory configuration.

11. In a timepiece having a timepiece mechanism, in combination, a base; ratchet wheel means rotatably mounted on said base and being operatively associated with said timepiece mechanism for actuating the same during rotation of said ratchet wheel means in one angular direction; pawl means for driving said ratchet wheel means and cooperating therewith in such a manner that when said pawl means moves forwardly in one direction it engages said ratchet wheel means positively and causes the same to rotate in said one angular direction and that when said pawl means moves backwardly in the opposite direction it engages said ratchet wheel means frictionally and tends to cause the same to rotate in the opposite angular direction; a tuning fork vibrator carried by said base and having a tine connected to said pawl means for reciprocating the same during oscillation of said vibrator, said tine, said pawl means and said ratchet wheel lying in the same plane said tine being oscillatable about an axis of oscillation and said pawl means being attached to said tine at a point thereof that lies on a line which passes through the point of engagement between said pawl means and said ratchet wheel means and is normal to a line passing through said point of engagement and through said axis of oscillation; and braking means frictionally engaging said ratchet wheel means with a braking force which is sufficiently great to prevent rotation of said ratchet wheel means in said opposite angular direction during backward movement of said pawl means, and which braking force is also sufficiently great to prevent rotation of said ratchet wheel means in said one angular direction under the influence of its inertia after said pawl means has completed its forward movement and commenced its backward movement, said ratchet wheel lying adjacent the upper end of said tine, the line extending through said pawl means and passing through said point of engagement forming with a line tangential to said ratchet wheel and also passing through said point of engagement an angle of about 30 degrees.

12. In a timepiece having a timepiece mechanism, in combination, a base; ratchet wheel means rotatably mounted on said base and being operatively associated with said timepiece mechanism for actuating the same during rotation of said ratchet wheel means in one angular direction; pawl means for driving said ratchet wheel means and cooperating therewith in such a manner that when said pawl means moves forwardly in one direction it engages said ratchet wheel means positively and causes the same to rotate in said one angular direction and that when said pawl means moves backwardly in the opposite direction it engages said ratchet wheel means frictionally and causes the same to rotate in the opposite angular direction; a tuning fork vibrator carried by said base and having a tine connected to said pawl means for reciprocating the same during oscillation of said vibrator, said tine, said pawl means and said ratchet wheel lying in the same plane, said tine being oscillatable about an axis of oscillation and said pawl means being attached to said tine at a point thereof that lies on a line which passes through the point of engagement between said pawl means and said ratchet wheel means and is normal to a line passing through said point of engagement and through said axis of oscillation; and means engaging said ratchet wheel means with a braking force to prevent rotation of said ratchet wheel means in said opposite angular direction during backward movement of said pawl means, said ratchet wheel lying adjacent the upper end of said tine, the line extending through said pawl means and passing through said point of engagement forming with a line tangential to said ratchet wheel and also

passing through said point of engagement an angle of about 30 degrees.

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