March 22, 1960 M. HETZEL 2,929,196

ELECTRIC TIMEPIECE

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FIG. 1

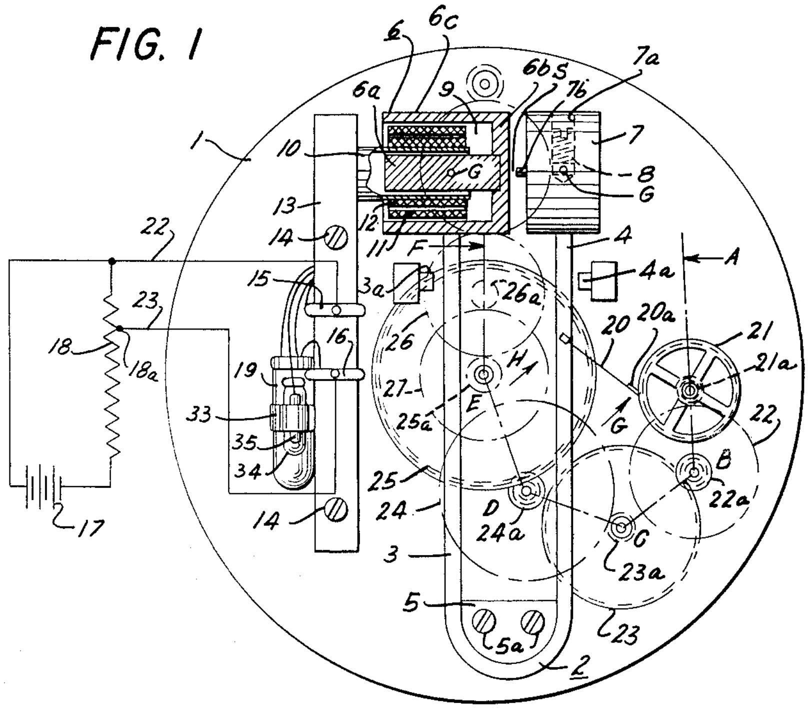
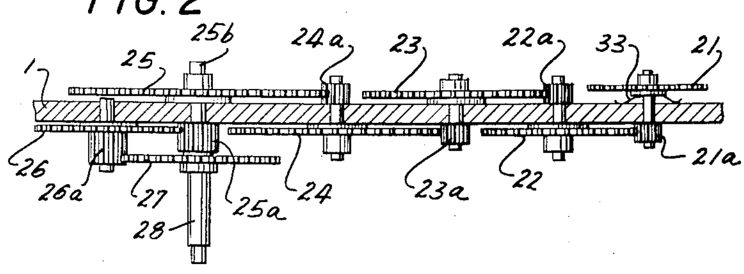


FIG. 2



INVENTOR.
Max Hetzel
BY Michael S. Striker
Agt.

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FIG. 3

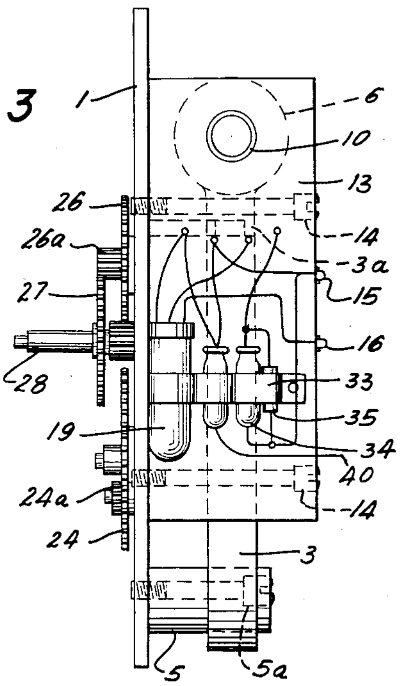


FIG. 6

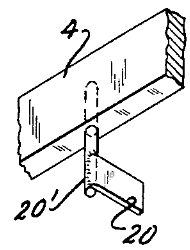


FIG. 5

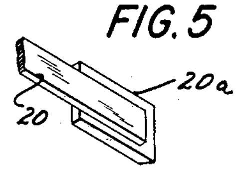
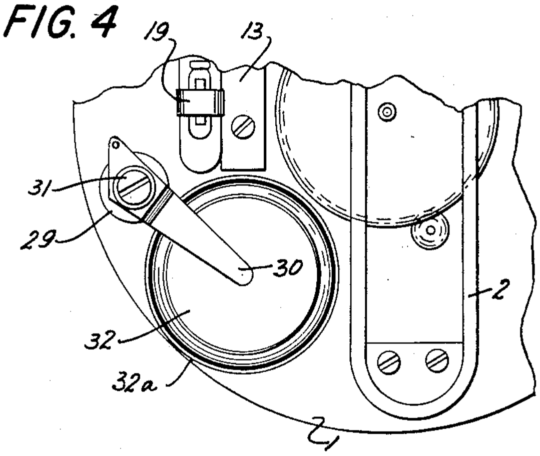


FIG. 4



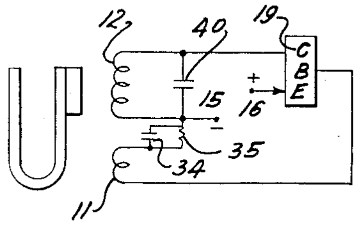


FIG. 7

INVENTOR.
Max Hetzel
BY Michael S. Striker
Agt

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FIG. 8

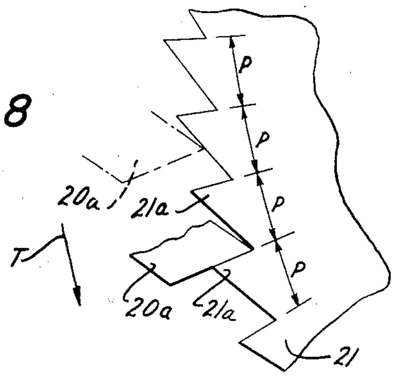


FIG. 9

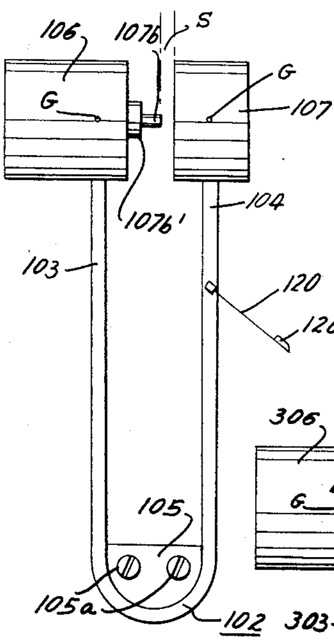


FIG. 10

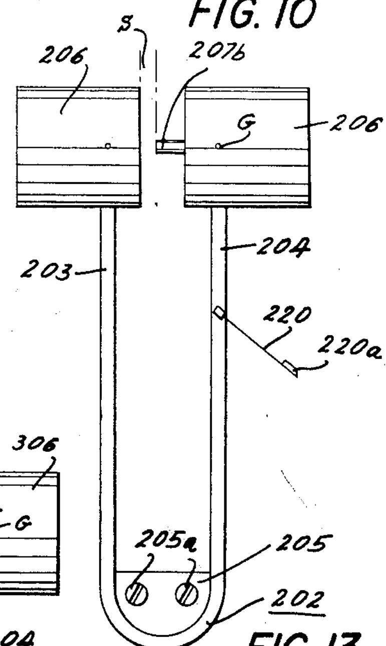
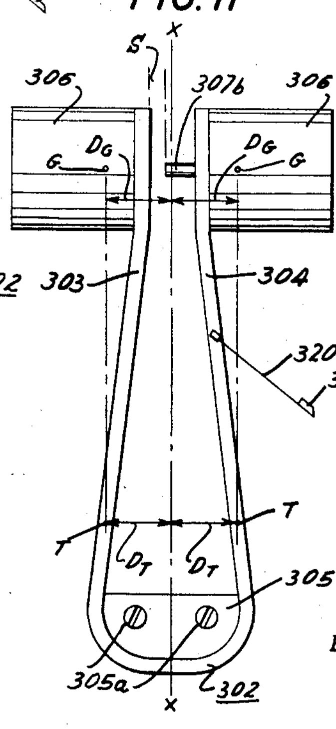


FIG. 11



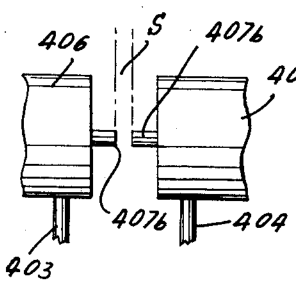
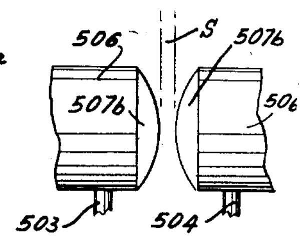


FIG. 12

FIG. 13



INVENTOR.
Max Hetzel
BY Michael S. Striker
Agt

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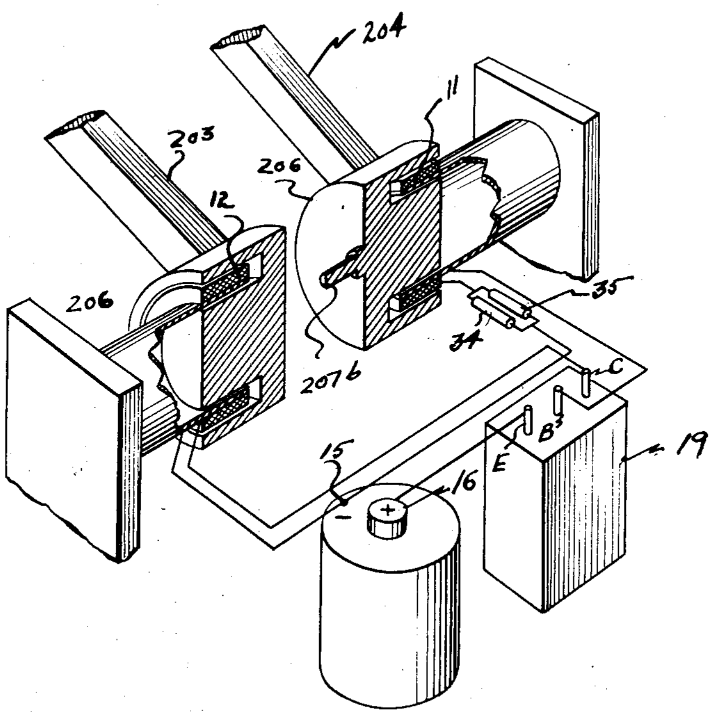

Fig. 14.

INVENTOR.
MAX HETZEL
BY Kenyon and Kenyon
ATTORNEYS

United States Patent Office

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Patented Mar. 22, 1960

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ELECTRIC TIMEPIECE

Max Hetzel, Biel, Switzerland, assignor to Bulova Watch Company, Inc., Jackson Heights, N.Y.

Application March 12, 1956, Serial No. 570,958

18 Claims. (Cl. 58—23)

The present invention is a continuation-in-part of the copending application Serial No. 565,452, filed February 14, 1956, and relates to electric timepieces.

It is an object of the present invention to provide an electrical timepiece having means for converting the oscillations of a vibrator such as a tuning fork or the like into rotary movements of the hands of the timepiece with means for controlling the amplitude of the oscillations so as to insure accuracy of the timepiece.

It is another object of the present invention to provide an electrical timepiece which is composed of simple and ruggedly constructed elements which are very reliable in operation.

With the above objects in view, the present invention mainly consists in that improvement in a timepiece having a timepiece mechanism which includes reciprocating driving means for driving the timepiece mechanism. The driving means are operatively associated with the timepiece mechanism in such a manner that the timepiece mechanism is driven by the driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length. A vibrator is connected to the driving means for reciprocating the same with a stroke the length of which is a function of or depends upon the amplitude of oscillation of the vibrator. The vibrator is so constructed and arranged as to have a maximum amplitude of oscillation at which the stroke length of the driving means equals the predetermined maximum stroke length. Also, means are provided for oscillating the vibrator at an amplitude at which the stroke length of the driving means is equal to at least the predetermined minimum stroke length, so that the driving means may drive the timepiece mechanism.

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 plan view of the interior of a timepiece according to the present invention when seen from the rear of the timepiece, Fig. 1 showing diagrammatically how the electrical leads may be connected to a storage battery or the like when the timepiece is used, for example, as a clock of an automobile;

Fig. 2 is a sectional elevational view taken along line A—B—C—D—E—F of Fig. 1 in the direction of the arrows;

Fig. 3 is a side elevational view of the structure of Fig. 1 as seen from the left side of the latter;

Fig. 4 is a fragmentary plan view similar to Fig. 1 showing a variation according to which the structure of Fig. 1 may be connected to a different source of electrical energy;

Fig. 5 is a fragmentary perspective view of a part of

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a pawl of the present invention as seen in the direction of arrow G of Fig. 1;

Fig. 6 is a perspective view illustrating the connection of a pawl to the tine of a tuning fork, the structure of Fig. 6 being shown in the direction of arrow H of Fig. 1;

Fig. 7 is a wiring diagram of the electrical circuit of the structure shown in the drawings;

Fig. 8 is a diagrammatic view illustrating the interaction of a pawl and ratchet wheel incorporated in a structure according to the present invention;

Fig. 9 is a diagrammatic showing of a modified embodiment of the present invention;

Fig. 10 is a diagrammatic view of another modified embodiment of the present invention;

Fig. 11 is a diagrammatic view of yet another modified embodiment of the present invention;

Fig. 12 is a fragmentary diagrammatic view of a still further modified embodiment of the present invention;

Fig. 13 is a fragmentary diagrammatic view of yet another modified embodiment of the present invention; and

Fig. 14 is a perspective view, partially in section, of another embodiment of a timepiece in accordance with the invention, the tuning fork construction corresponding to that in Fig. 10 and the electrical circuit associated therewith being similar to that in Fig. 7.

Referring now to the drawings, it will be seen that the timepiece includes a base plate **1** which is made of a circular plate having a substantially constant thickness. A vibrator **2** which is preferably of the tuning fork type is fixed to a member **5** as by soldering or welding or the like, and this member **5**, in turn, is fixed to the base plate **1** by a pair of screws **5*a***. As is clearly shown in Figs. 1 and 3, the member **5** is connected to the tuning fork **2** only at that part thereof which interconnects the tines **3** and **4**, so that the latter are maintained in spaced relation to the base plate **1** and are free to oscillate.

At the free end of the tine **3** there is located a permanent magnet **6** in the form of a hollow cylinder which is open at one end and which has an end wall **6*b*** closing the cylinder **6*c***, this end wall **6*b*** carrying a magnetic bar **6*a*** which is of very strong magnetic material, as, for example, Alnico.

The other tine **4** of the tuning fork **2** carries at its free end a balance weight **7** which may simply be in the form of a cylindrical block fixed in the manner shown in Fig. 1 to the free end of the tine **4**. The tines **3** and **4** and the masses of the permanent magnet **6** and the balance weight **7** are so chosen that the tine **3** and the permanent magnet **6** on the one hand and the tine **4** and the balance weight **7** on the other hand have approximately the same natural frequency so that the tuning fork will not require an undesirable large amount of damping. Also, the arrangement of the parts is such that the centers of gravity G of the permanent magnet **6** and the balance weight **7** are in alignment with the tines 3 and **4**, respectively. As a result, it is possible for the tines **3** and **4** to oscillate at constant frequency while requiring an almost negligible amount of energy, as set forth in copending application Serial No. 565,451, filed February 14, 1956 and entitled "Tuning Fork Oscillator."

The counter weight **7** carries an abutment element **7*b*** which is preferably made of non-magnetic material, as, for example, brass. The abutment element **7*b*** extends toward the permanent magnet **6** and is spaced therefrom a distance *s*.

As is well known, the tines of a vibrating tuning fork type vibrator normally oscillate toward and away from each other, i.e., inward movement of one tine from its normal rest position is accompanied by a corresponding inward movement of the other tine and outward movement of one tine is accompanied by a corresponding outward movement of the other tine. Also, the inward deflection of each tine is equal to its outward deflection, so that the amplitude of oscillation of each tine is equal to twice the deflection of each tine from its rest position to its inner deflected position.

It will be seen, therefore, that the maximum amplitude of oscillation of each tine 3 and 4 is equal to the length of the distance *s* inasmuch as the maximum possible inner deflection of each tine is equal to one-half *s*.

The purpose of the abutment element 7*b* and the factors influencing the selection of the distance *s* will be discussed below.

Also, suitable abutments 3*a* and 4*a* are carried by the base plate 1 and serve to limit the outwardmost deflections of the tines 3 and, respectively, to prevent damage by reason of excessive shocks. The distances between tine 3 and abutment 3*a*, tine 4 and abutment 4*a* is much bigger than the above-described distance *s*.

If desired, the balance weight 7 may be provided with a threaded bore 7*a* in which a screw member 8 is threadedly located. The screw member 8 is shorter than the length of the threaded bore so that the screw member may be shifted toward or away from the tine 4 along a line forming an extension of the latter. In this way, the center of gravity of the balance weight 7 is shifted along this line simply by varying the position of the screw 8. As a result, the natural frequency of the tine 4 may be varied, the center of gravity of the balance weight 7, however, at all times remaining in registration with the tine 4. Inasmuch as the natural frequency of the entire tuning fork 2 is the average of the natural frequency of the two tines, it is possible to change the natural frequency of the entire tuning fork by shifting the screw 8. In this way, it is possible to regulate the time which is kept by the timepiece. Thus, if there are relatively small variations between the natural frequencies of the tines and the weight and permanent magnet, respectively carried thereby, such small variations in the natural frequencies will not influence the operation of the timepiece. When the latter is first manufactured, the relative natural frequencies of the tines and the parts carried thereby are so regulated, as, for example, by filing off a part of one tine, that the timepiece keeps perfect time to within plus or minus three minutes, for example. By shifting the screw member 8 in the balance weight 7 it is possible to provide a very fine adjustment which will enable the timepiece to keep accurate time within this range of plus or minus three minutes per month.

The above described adjusting or compensating arrangement is described in copending application Serial No. 565,452 filed February 14, 1956 and entitled "Electric Timepiece."

In the chamber 9 within the drum magnet 6, there is located a tubular carrier 10 which is fixed to a support 13, the latter in turn being fixed to the base plate 1 by means of screw members 14, as is shown in Figs. 1 and 3. The tubular member 10 freely surrounds the core 6*a* without contacting the latter, and the tubular member 10 carries a pair of coils 11 and 12, the coil 12 having approximately five times as many turns as the coil 11. The core 6*a* has sufficient clearance within the tube 10 to avoid contacting the latter during oscillations of the tines 3 and 4 of the tuning fork. Thus, the coils form with the permanent magnet 6 a transducer which, together with the tuning fork 2, forms a tuning fork oscillator of the same general type as that disclosed in copending application Serial No. 436,949, filed June 15, 1954 and entitled "Electronic Device for the Operation of a Timepiece Movement."

At the left face of the support 13, as viewed in Fig. 1, and as is shown in Fig. 3, there is fixed a resilient strap 33 which serves to mount on the support 13 a capacitor 34, a resistor 35, a transistor 19, and a capacitor 40. Furthermore, the support 13 carries a pair of insulated electrical terminals 15 and 16 which are electrically connected to the lines 22 and 23 which in turn are connected to a source of electrical energy. According to the embodiment of the invention shown in Fig. 1, the source of energy is the storage battery 17 of an automobile. In general the voltage of such an automobile battery is too great for the purposes of operating a timepiece of the type disclosed, so that this battery is not connected directly to the timepiece. The lines 22 and 23 are connected in the manner shown in Fig. 1 to the resistor 18, and the end 18*a* of the line 23 forms with the resistor 18 a voltage divider, this voltage divider being located outside of the timepiece, although it could of course be located within the casing of the timepiece and fixed to the base plate 1, if desired.

When the above described electronic circuit is connected to the source of energy, the electrical circuit is closed and the oscillations of the tuning fork are started and are maintained by the source of energy. The electrical circuit is shown schematically in Fig. 7, coil 12 acting as the drive coil for the tuning fork and coil 11 as a sensing coil. In operation, transistor 12 is rendered conductive for a relatively brief period during each operating cycle by a voltage induced in sensing coil 11 and applied to base B to overcome a cut-off bias imposed thereon by condenser 34 and resistor 35. During the conduction period of the transistor current is caused to flow through drive coil 12 which is connected to the battery terminals 15 and 16 in series with the transistor electrodes C and E. The tuning fork starts oscillating as soon as the circuit is closed because it is quite sensitive and picks up any vibrations which are present in the surrounding atmosphere or in the base plate 1. With an arrangement as described above it is possible to obtain a frequency constant to two parts in 10^7, while for a timepiece of the type described above a frequency constant to one part in 10^5 is more than adequate. The oscillations of the tuning fork must be converted into a rotary movement in order to be useful in the timepiece, and this conversion can take place by the transmission means illustrated in Figs. 1, 2, 5 and 6.

A pawl 20 is carried by the tine 4 of the tuning fork 2, this pawl 20 being in the form of a relatively light leaf spring being fixed to the tine 4 by means of a pin 20', as shown in Fig. 6. The tine 4 is formed with a relatively shallow bore which does not extend more than one quarter of the way through the tine 4 and into which bore the pin 20' is pressed, so that in this way the natural frequency of the tine 4 is influenced to but a very negligible extent. The leaf spring 20 is fixed to the pin 20' as by being soldered thereto, in the manner shown in Fig. 6, and at its free end leaf spring 20 carries the tooth member 20*a* made of a very hard material such as glass or hardened steel. Also, precious or semi-precious stones such as rubies or sapphires are particularly suitable for this purpose. As is evident from Fig. 5, the member 20*a* is wider than the leaf spring 20 and extends beyond the latter, and this member 20*a* is fixed to the leaf spring 20 by a suitable adhesive material, for example. The member 20*a* needs a sharp edge, which may have even an angle of 90 degrees between the two surfaces.

This member 20*a* of the pawl cooperates with the teeth of the ratchet wheel 21 so that the oscillations of the tine 4 transmit turning impulses to the ratchet wheel 21 through the pawl 20. In this way the ratchet wheel 21 is turned through a predetermined angle at every oscillation. As is evident from Fig. 2, the ratchet wheel 21 and the pinion 21*a* are fixed to a common shaft which extends through the base plate 1. In addition, this common shaft extends through an opening of dished spring 33 which bears against part of the ratchet wheel 21 and urges the latter away from the base plate 1, so that dished spring 33 acts as a brake retarding the turning movement of the ratchet wheel 21. The spring 33, the ratchet wheel 21, as well as the pawl 20 and member 20*a* are carefully designed and chosen so that at each oscillation the turning movement transferred to the ratchet wheel **21** by the leaf spring **20** will result only in a turning of the ratchet wheel in the desired direction through a distance of one tooth. In other words the arrangement is such that the ratchet wheel **21** cannot overrun or turn freely beyond the distance through which it is turned by the pawl. Furthermore the frictional resistance provided by the spring **33** is such that during the return movement of the pawl **20** the ratchet wheel **21** also does not turn and the tooth member **20***a* runs over a tooth of the ratchet wheel to engage in the next space between the teeth. In this way a turning movement is imparted to the ratchet wheel **21** which compels the latter to rotate at a rate, i.e., at a number of revolutions per unit time, which has a direct relation to the rate of oscillation of the tuning fork **2**.

Inasmuch as the tuning fork oscillates at a constant rate, the ratchet wheel **21** also turns at a constant speed and in one direction. A gear train is provided to transmit the turning of the ratchet wheel **21** to the hands of the clock, and this gear train includes the pinion **21***a*, the gear **22** meshing with the pinion **21***a* and turning together with the pinion **22***a* which meshes with the gear **23** which turns together with the pinion **23***a*. The pinion **23***a* meshes with the gear **24** which turns the pinion **24***a*, the latter meshing with the gear **25** which turns together with the pinion **25***a*. The gear **25** is fixed as by a press fit to the shaft **25***b* to which the pinion **25***a* also is fixed, and this shaft **25***b* extends all the way up to the unillustrated face of the clock which carries the numbers.

The frequency of oscillations of the tuning fork and the number of teeth of the ratchet wheel **21** as well as the different transmission ratios between the several driving and driven gears are so chosen that the shaft **25***b* makes one complete revolution in an hour. Thus, the minute hand is fixed to the shaft **25***b*.

The speed of the minute gear **25** is reduced to one twelfth in a known way. Thus, the gear **25***a* meshes with a gear **26** which turns together with the pinion **26***a*, the latter in turn meshing with a gear **27** affixed to the sleeve **28** freely turnable on the shaft **25***b*. These gears **25***a*, **26**, **26***a*, and **27** give to the sleeve **28** a speed of rotation which is one twelfth that of the shaft **25***b*, so that the sleeve **28** turns through a comptete revolution in twelve hours, and thus the hour hand is fixed to the sleeve **28**.

If, for example, the tuning fork oscillates at 175 cycles per second, then the various pinions and gears can have the following numbers of teeth to provide the desired transmission to enable accurate time to be kept from the tuning fork.

Pinion or gear:	Number of teeth
Ratchet wheel **21**	360
Pinion **21***a*	6
Gear **22**	30
Pinion **22***a*	6
Gear **23**	36
Pinion **23***a*	6
Gear **24**	42
Pinion **24***a*	6
Minute wheel **25**	50
Pinion **25***a*	10
Gear **26**	30
Pinion **26***a*	8
Hour wheel **27**	32

A consideration of the above numbers of teeth will show that the minute wheel makes one revolution an hour and the hour wheel makes one revolution in twelve hours.

With the above described embodiment of the timepiece the source of energy is located outside of the timepiece and is in the illustrated example the battery of an automobile. However, the timepiece of the invention, which may be a wrist watch instead of an automobile clock, may carry its own source of energy within its own housing. Thus, Fig. 4 shows an arrangement where the base plate **1** is provided with a depression which receives a miniature battery **32** which may have a terminal voltage of 1.35 volts, and this battery **32** is maintained within the depression **32***a* of the base plate **1** by an electrically conductive springy member **30** which is affixed by a screw **31** to a block **29** of insulating material, this block being fixed in a known way as by a screw or the like to the base plate **1**. The force of the spring **30** keeps the battery **32** in position within the recess **31**. The casing of the battery **32** which engages the electrically conductive base plate **1** forms the negative pole of the battery while the positive pole thereof is formed by the cover of the battery which engages the member **30**. This member **30** is insulated from the base plate **1** by the block **29**, although if desired the member **30** can also be insulated from block **29** and screw **31** in any suitable way as by suitable washers and a suitable sleeve into which the screw **31** extends. With the arrangement of Fig. 4 the electrically conductive springy member **30** is connected with a suitable lead to the positive terminal **16** carried by the support **13** while the negative terminal **15** is in this case connected electrically with the base plate **1**.

A wiring diagram illustrating the electrical circuit is shown in Fig. 7. Thus, referring to Fig. 7 it will be seen that the tuning fork together with the permanent magnet are shown diagrammatically at the left. Furthermore the transistor **19** is shown with its emitter, base, and collector terminals respectively indicated by the letters E, B, and C, respectively. The terminal **16** is connected electrically with the emitter connection E, while the collector connection C is connected with one end of the coil **12** which has approximately five times the number of turns of the coil **11**, as was pointed out above, the other end of the coil **12** being connected to the negative terminal **15**. In parallel with the coil **12** is located the capacitor **40** which serves to prevent undesired oscillations. Furthermore, the capacitor **34** and resistor **35** are interconnected between the coil **11** and the negative terminal **15**, in the manner shown in Fig. 7, and the coil **11** is connected electrically to the base connection of the transistor **19**, in the manner shown in Fig. 7.

It will be seen from the above that the reciprocation of the pawl **20** is brought about by the oscillation or vibration of the vibrator **2**, the length of the stroke of reciprocation of the pawl being a function of or dependent upon the amplitude of oscillation of the tine **4**. It will also be understood that the arrangement of the parts is such that normally each reciprocation of the pawl brings about an angular rotation of the ratchet wheel which corresponds to the pitch of each ratchet tooth. Thus, the stroke length of the pawl must not only be sufficiently great so that the pawl will, during successive reciprocation, engage different teeth, but also, the stroke length of the pawl should not be so great that the pawl engages, during successive reciprocations, non-successive teeth. If the latter were to occur, i.e., if, during successive reciprocations, the pawl were occasionally to engage alternate teeth, that particular reciprocation of the pawl would be accompanied by a double angular displacement of the ratchet wheel. Since, in practice, a timepiece particularly of the watch type is often subjected to shocks, the amplitude of oscillation of the tuning fork may become sufficiently great, at least temporarily, so as to cause the pawl to engage, during successive reciprocations, non-adjacent or non-successive ratchet teeth. This, in turn, would bring about inconstant and inaccurate activation of the timepiece mechanism.

As may best be seen in Fig. 8, the pawl should move in such a manner that the tooth **20***a*, in a direction T tangential to the ratchet wheel at the point of engagement between the tooth **20***a* and the ratchet wheel, reciprocates with a stroke the length of which is greater than the distance P and smaller than twice this distance, the distance P representing the pitch of the ratchet teeth.

It is clear that if the tooth **20a** does not reciprocate with a stroke the length of which exceeds the distance P, the tooth **20a** would not, during successive reciprocations, engage successive teeth but would instead simply remain in engagement with the same tooth. Also, it will be seen that if the tooth **20a** reciprocates with a stroke the length of which exceeds the distance 2P, the tooth **20a** would engage non-consecutive or alternate teeth. If this were to occur then each reciprocation during which the stroke length of the tooth **20a** exceeded the distance 2P would bring about a double angular displacement of the ratchet wheel **21**.

It will be readily understood that the stroke length of the tooth **20a** in the direction T is a function of or is dependent upon the amplitude of oscillation of the tine **4**. Thus, in order for the tooth **20a** to reciprocate with a stroke length equal to at least P, the tine **4** will have to oscillate with a certain minimum amplitude. The above described electrical means shown schematically in Fig. 7, are capable of oscillating the tine **4** at at least such minimum amplitude.

Also, it will be understood that in order for the stroke length of the tooth **20a** not to exceed 2P, the maximum amplitude of oscillation of the tine **4** may not exceed a certain maximum amplitude. Preferably, the above described electrical means will not oscillate the tine **4** above this maximum amplitude, but shocks to which a timepiece is very often exposed may be sufficient to cause the tine **4** to oscillate above this maximum amplitude for many cycles until damping to about the normal amplitude and to turn during this time the ratchet wheel too quick. However, the abutment element **7b** carried by the balance weight **7** prevents the tines **3** and **4** from oscillating above an amplitude corresponding to the distance *s*, as set forth above. Accordingly, the distance *s* is so selected that the tines **3** and **4** may oscillate at a maximum amplitude which corresponds to reciprocation of the tooth **20a**, in the direction T, with a stroke length less than 2P. In this way, the tooth **20a** cannot, during oscillation of the tuning fork, skip any of the teeth **21a** of the ratchet wheel **21**. Consequently, each oscillation of the tuning fork and consequently each reciprocation of the pawl **20** brings about an angular movement of the ratchet wheel **21** which corresponds to the pitch P of the ratchet teeth **21a**.

In practice, the electrical means for oscillating the tuning fork are so constructed and arranged that the tines are oscillated at such amplitude as will bring about reciprocation of the tooth **20a** in the direction T with a stroke length equal to approximately 1.5P. Thus, in Fig. 8 the forwardmost position of the tooth **20a** is shown in solid lines whereas the normal backwardmost position is shown in dotted lines.

In the embodiment illustrated in Fig. 9, the tuning fork **102** having tines **103** and **104** is adapted to be mounted on the base plate of the timepiece mechanism by means of the member **105**, the latter being screwed onto the base plate by means of screws **105a**. The tines **103** and **104** respectively carry a permanent magnet **106** and a balance weight **107**, the respective centers of gravity of these members being in registration with the respective tines. The tine **104** carries a pawl **120** having a tooth **120a**, as described above. The instant embodiment differs from the above described one in that the abutment element **107b** instead of being carried by the balance weight **107** is carried by the permanent magnet **106**. As described above, the element **107b** may be made of non-magnetic material, such as brass. If desired, however, the element **107b** may be made of magnetic material but be magnetically insulated from the permanent magnet **106** by means of a partition element **107b'** which is made of non-magnetic material. The right free end of the element **107b**, as viewed in Fig. 9, is spaced a distance *s* from the balance weight **107**, and the function and mode of operation of the device is identical to that of the above described embodiment.

In the embodiment illustrated in Fig. 10, the tuning fork **202** having tines **203** and **204** is adapted to be secured to the base plate of a timepiece by means of a member **205**, the latter being screwed onto the base plate by means of screws **205a**. The tine **204** carries a pawl **220** having a tooth **220a** adapted to cooperate with the ratchet wheel in the manner described above. The tines **203** and **204** each carry a permanent magnet **206**, the respective centers of gravity of which are in alignment or registration with the respective tines, so that the instant embodiment differs from the above described one in that two permanent magnets are provided, there being no balance weight corresponding to the element **7** of Fig. 1. In the instant embodiment the electrical means for oscillating the tuning fork may be of the construction more fully described in the above mentioned copending application Serial No. 436,949 filed June 15, 1954 and entitled "Electronic Device for the Operation of a Timepiece Movement," now abandoned. The electrical arrangement as shown in Fig. 14 is essentially the same as that in Fig. 7, save that coils **11** and **12** cooperate with separate permanent magnets **206** rather than with a common magnet. One of the permanent magnets **206** carries an abutment element **207b** which is spaced from the other permanent magnet a distance *s*, the function and operation of the device being identical to the above described ones.

In the embodiment illustrated in Fig. 11, the tuning fork **302** includes a pair of tines **303** and **304**, the axis of symmetry of the tuning fork being indicated by the line X—X. As in the above described embodiments, a member **305** serves to mount the tuning fork onto the base plate of a timepiece, as, for example, by means of screws **305a**.

The tines of the tuning fork are inclined toward each other and converge toward each other as they approach their free ends so that the tuning fork **302** has the substantially triangular configuration indicated in Fig. 11. A pair of permanent magnetic drums **306** are fixed at their end faces respectively to the outer faces of the free ends of the tines, it being understood that one of the drums **306** may be replaced by a suitable balance weight of the type described in connection with the embodiments illustrated in Figs. 1 and 9. The arrangement of the parts is such that the center of gravity of each magnet is spaced a distance D_G from the axis of symmetry X—X. This distance is so selected as to be substantially equal to the distance D_T which is the distance that each point T is spaced from the axis of symmetry X—X. The point T of each tine represents that axis about which the point of gravity of the permanent magnetic drum or balance weight oscillates or pivots. In practice, the axis T of each tine will be located in the lowermost third of the tine.

As a result, the frequency of oscillation of the tuning fork is maintained constant at a desired value and only a minimum amount of energy is required to maintain the vibrations or oscillations, this as set forth in full in copending application Serial No. 565,451 filed February 14, 1956 and entitled "Tuning Fork Oscillator."

The tine **304** carries a pawl **320** having a tooth **320a** which is adapted to cooperate with a ratchet wheel, in the manner described above, and one of the tines carries the abutment element **307b** which is fixed to the inner face of the free end portion of the tine. As is clearly shown in Fig. 11, the free end of the abutment element **307b** is spaced a distance *s* from the inner face of the free end portion of the other tine so as to limit the maximum amplitude of oscillation of the tuning fork.

In the embodiment illustrated in Fig. 12, each of the tines **403** and **404** carries a permanent magnet **406**, it being understood that one of the permanent magnets may be replaced by a suitable balance weight. The instant embodiment differs from the above described ones in that each of the permanent magnets **406** carries an abutment element **407*b***, these elements being spaced from each other a distance *s* and cooperating with each other in such a manner that when the amplitude of oscillation of the tines is equal to the maximum permissible amplitude, the abutment elements will engage each other thereby preventing the tines from oscillating at an amplitude greater than this maximum amplitude.

In the embodiment illustrated in Fig. 13, the tines **503** and **504** each carry a permanent magnet **506**, it being understood that one of the permanent magnets may be replaced by a suitable balance weight. In the instant embodiment, each of the permanent magnets **506** either carries or is formed with an abutment portion **507*b*** which may be substantially frusto-conical or dome-shaped as shown in Fig. 13. The respective inwardmost parts of the portion **507*b*** are spaced from each other a distance *s*, thereby limiting the maximum amplitude of oscillation of the tines.

Additionally, it will be understood that any suitably shaped abutment means may be provided for limiting the maximum amplitude of oscillation of the tines. For example, the abutment means may be connected to or be integral with the tines proper. Also, it is not essential that the abutment means be located between the free end portions of the tines, and they may be so arranged as to be located physically exteriorly of the space between the tines.

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 electric timepieces differing from the types described above.

While the invention has been illustrated and described as embodied in an electric timepiece incorporating a tuning fork type vibrator, 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.

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 tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length; and abutment means arranged between said tines and carried by at least one of said tines for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, whereby said driving means may drive said timepiece mechanism.

2. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length; and an abutment element for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment element being arranged between said tines, carried by one of said tines and being adapted to engage the other of said tines, whereby said driving means may drive said timepiece mechanism.

3. The combination defined in claim 2 wherein said abutment element is made of non-magnetic material.

4. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation therewith is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment means including a pair of cooperating abutment elements arranged between said tines and carried by said tines, respectively, whereby said driving means may drive said timepiece mechanism.

5. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including a pair of electrical components carried by said tines, respectively, in the regions of their respective free ends, each of said components being so constructed and arranged that its center of gravity, when each respective tine is in its rest position, is spaced from the axis of symmetry of said vibrator a distance which is substantially equal to the distance which the pivot axis about which each tine pivots during oscillation is spaced from said axis of symmetry; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum

stroke length, whereby said driving means may drive said timepiece mechanism.

6. The combination defined in claim 5 wherein said tines, when they are in rest position, extend substantially parallel to each other throughout their entire lengths and wherein the centers of gravity of the respective components are in alignment with the respective tines.

7. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including an electrical component carried by one of said tines in the region of its free end and a balance weight component carried by the other of said tines in the region of its free end, each of said components being so constructed and arranged that its center of gravity, when each respective tine is in its rest position, is spaced from the axis of symmetry of said vibrator a distance which is substantially equal to the distance which the pivot axis about which each tine pivots during oscillation is spaced from said axis of symmetry; and a pair of abutments carried by said components and adapted to engage one another for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, whereby said driving means may drive said timepiece mechanism.

8. The combination defined in claim 7 wherein said tines, when they are in rest position, extend substantially parallel to each other throughout their entire lengths and wherein the centers of gravity of the respective components are in alignment with the respective tines.

9. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including a pair of electrical components carried by said tines, respectively, in the regions of their respective free ends; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment means including at least one abutment element carried by one of said components and adapted to engage the other of said components when said tines oscillate at said maximum amplitude, whereby said driving means may drive said timepiece mechanism.

10. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including an electrical component carried by one of said tines in the region of its free end and a balance weight component carried by the other of said tines in the region of its free end; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment means including at least one abutment element carried by one of said components and adapted to engage the other of said components when said tines oscillate at said maximum amplitude, whereby said driving means may drive said timepiece mechanism.

11. The combination defined in claim 10 wherein said abutment element is carried by said balance weight component.

12. The combination defined in claim 10 wherein said abutment element is carried by said electrical component.

13. The combination defined in claim 12 wherein said abutment element is made of non-magnetic material.

14. The combination defined in claim 12 wherein said abutment element includes an engaging portion adapted to engage said balance weight component and an insulating portion interposed between said engaging portion and said electrical component, said insulating portion being made of non-magnetic material and magnetically insulating said engaging portion from said electrical component.

15. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a pair of oscillatable tines; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including a pair of electrical components carried by said tines, respectively, in the regions of their respective free ends; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment means including a pair of abutment elements carried by said components, respectively, and adapted to engage each other when said tines oscillate at said maximum amplitude, whereby said driving means may drive said timepiece mechanism.

16. The combination defined in claim 15 wherein each of said abutment elements is integral with the respective component carrying it.

17. In a timepiece having a timepiece mechanism, in combination, a tuning-fork type vibrator having a base portion carrying a pair of oscillatable tines, said tines converging toward each other in such a manner that their free ends are closer to each other than those ends thereof at which said tines join said base portion, said tines having at their free ends end portions which extend substantially parallel to each other and each of which end

portions has an inner face directed toward the other tine and an outer face opposite its inner face; reciprocating driving means for driving said timepiece mechanism and being operatively associated therewith in such a manner that said timepiece mechanism is driven by said driving means when the length of the stroke of reciprocation thereof is between a predetermined minimum stroke length and a predetermined maximum stroke length, said driving means being connected to one of said tines for being reciprocated by the same with a stroke the length of which is a function of the amplitude of oscillation of said tines; electrical means for oscillating said tines of said vibrator at an amplitude at which the stroke length of said driving means is equal to at least said predetermined minimum stroke length, said electrical means including a pair of electrical components carried by said tines, respectively, at their respective free end portions with each component being on the respective outer face of each respective free end portion; and abutment means for limiting the amplitude of oscillation of said tines to a maximum amplitude of oscillation at which the stroke length of said driving means equals said predetermined maximum stroke length, said abutment means including at least one abutment element carried by one of said tines at its free end portion and projecting from said inner face thereof toward the inner face of the end portion of the other of said tines, said abutment element being adapted to engage the last-mentioned inner face when said tines oscillate at said maximum amplitude, whereby said driving means may drive said timepiece mechanism.

18. The combination as defined in claim 17 wherein each of said components is so constructed and arranged that its center of gravity, when each respective tine is in its rest position, is spaced from the axis of symmetry of said vibrator a distance which is substantially equal to the distance which the pivot axis about which each tine pivots during oscillation is spaced from said axis of symmetry.

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