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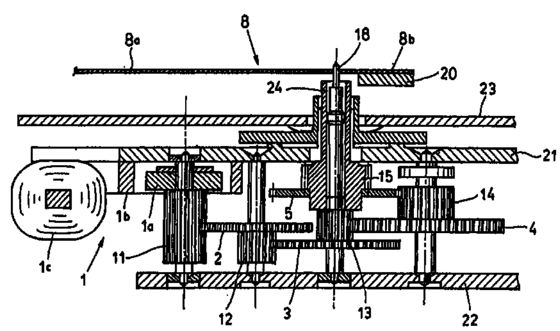
(54) ANALOG ELECTRONIC CLOCK

(57) In an analog electronic timepiece according to the present invention, a step motor (1) which retains a small holding energy is used, and in order to make the value of a disturbance energy which the step motor (1) receives through an external impact less than the holding energy value which the step motor (1) retains, a weight 20 is added, to lessen a moment of the whole rotary body, at least to a part of the rotary body including a hand (8) and train wheels (11, 2, 12, 3) for the rotation of the hand. Alternatively, a thin part, a through hole, or a notch may be formed at least in a part of said rotary body, or a part of the rotary members may be formed by a combination of members with different specific gravities from each other. Transmission of the disturbance energy occurring at the hand part to the step motor (1) may be prevented by providing a reverse transmission preventing gear at a part of said train wheels.

FIG. 1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a analog electronic timepiece for indicating time using bands, more specifically, to a technology for further reducing power consumption of the analog electronic timepiece and for diversifying the hands.

BACKGROUND TECHNOLOGY

[0002] In a time indicating system of a timepiece (watch or clock), in addition to accuracy, decoration is also required, and analog indication is superior due to its indication quality and its possible variety in design. The timepiece in which a step motor is used for an actuator is widespread.

[0003] Fig. 5 is a schematic perspective view of a conventional analog electronic timepiece showing a state in which force is transmitted from a step motor to bands via train wheels. In a standard three-hand timepiece, as shown in Fig. 5, a rotor 1a of a step motor 1, a fifth wheel 2, a second wheel 3, a third wheel 4, a center wheel 5, a minute wheel 6, and a hour wheel 7 are linked together in due order via pinions 11 to 16. Therewith, a second hand 8 which is integrated with the second wheel 3 and the pinion 13, a minute had 9 integrated with the center wheel 5 and the pinion 15, and an hour hand 10 integrated with the hour wheel 7 perform predetermined traveling motions. It is noted that the second hand 8, the minute hand 9 and the hour hand 10 are actually fitted to one another to rotate on the same axis, and are shown spread out for the sake of clarity.

[0004] The step motor 1 comprised of the rotor 1a, a stator 1b and a coil 1c requires a holding energy for preventing each of hands 8, 9, and 10 from being subject to a hand-skip phenomenon on an external impact, in addition to a driving energy required for driving each of hands 8, 9, and 10. The step motor 1 is designed in such a manner that both energy values meet the timepiece requirements.

[0005] In designing a conventional step motor for a timepiece, a required holding energy value according to the hands in use is determined first, and then a motor is designed in such a manner to satisfy the above value, in order to meet the timepiece requirements. Thereafter, suitable driving conditions are set within the above range.

[0006] The driving energy value is thus not conclusively optimized. Further, if only normal movement of hands is necessary, it will be possible to realize the step movement of hands with a driving energy value smaller than those required presently.

[0007] Normallly, holding energy always exists in a step motor as magnetic potential (resistance force to moving from a still point), and only portions of energy exceeding the magnetic potential out of an input energy is effective kinetic energy. Therefore, reduction of the holding energy value seems to be effective to lessen the power consumption, but from the viewpoint of holding bids as described above, the holding energy value can not be sufficiently reduced in the conventional analog electronic timepiece.

[0008] The driving energy value in the description does not mean the so-called whole given energy value but the effective energy value (the resultant value obtained by subtracting the holding energy value from the whole energy value) which is required when a hand non-steadily rotates a certain angle in a set period of time. Without the driving force exceeding the above value, the expected rotary motion can not be obtained.

[0009] The holding energy value means the energy value which is required for holding a hand so as to prevent a hand-skip phenomenon on an external impact, which is unconditionally determined from the step motor requirements.

[0010] In the recent electronic timepiece, an inconvenience of replacement of batteries once per several years is pointed out, it is desired that replacement of batteries is made unnecessary. As a measure to that, increase in capacity of a battery and reduction in power consumption are considered, but a large-size battery can not be used for a wristwatch due to limitation of outer dimensions. Furthermore, the electro-mechanical conversion efficiency of the step motor itself already comes to a limit thereof, therefore a more drastic reduction of the power consumption can not be expected using conventional methods.

[0011] In the conventional electronic timepiece, as described above, the value of the holding energy is set to be larger than that of the disturbance energy that occurs at the hand, part by an external impact, in order to prevent a hand-skip phenomenon. Which means, conversely, that the hand can not be held when the disturbance energy value exceeds the holding energy value.

[0012] The disturbance energy value, which means the magnitude of an external impact, relates to the magnitude of inertial moment (inertia) with consideration of imbalance caused by a degree of unbalanced moment of the rotary body including hands and train wheels, with respect to the rotational axis thereof.

[0013] Concerning with bands, since the shape of the hand is restricted, the disturbance energy value is greatly influenced by the magnitude of inertial moment. For instance, if hands are made larger or different in shape from what should be, giving priority to visual design, a problem would arise that the inertial moment increases according to the amount of imbalance being larger, thereby the disturbance energy value easily exceeds the holding energy value.

[0014] Under the present circumstances as described above, it is a serious problem to find bow to lessen the power consumption of the electronic timepiece and to realize a system in which replacement of batteries is made unnecessary. In order to lessen the power consumption, the aforesaid holding energy needs to be reduced.

[0015] In accomplishing that purpose, it is a problem to prevent a hand-skip phenomenon from occurring even when the holding energy value of the step motor is small, while obtaining flexibility of designs by eliminating limiting factors on design of the hand.

[0016] An object of the present invention is to solve the above problems and to achieve a further reduction in power consumption of the electronic timepiece by reducing the aforementioned holding energy value, while satisfying the timepiece requirements.

[0017] Another object is to obtain further flexibility of designs by eliminating limiting factors on bands to prevent a hand-skip phenomenon.

DISCLOSURE OF THE INVENTION

[0018] This invention is structured as follows, to achieve the aforesaid objects in an analog electronic timepiece having: hands for indicating time; a step motor having a holding energy for holding the hands while standing still and generating a driving energy which exceeds the holding energy while driving the hands; and train wheels for transmitting the movement of the step motor to the hands.

[0019] In order to lessen a moment of the whole rotary body, a weight is added at least to apart of the rotary body including the hands and the train wheels where an external impact causes a disturbance energy which is larger than the holding energy value possessed by the step motor, so that the disturbance energy value which the above step motor receives is made smaller than the above holding energy value.

[0020] Alternatively, a thin part, a through hole, or a notch may be formed, to lessen the moment of the whole rotary body, at least in a part of the rotary body.

[0021] Furthermore, at least a part of the rotary members of the above rotary body may be formed by a combination of members with different specific gravities from each other, to lessen the moment of the whole rotary body.

[0022] In these analog electronic timepieces, M and I are preferably set to satisfy the relation below:

$$M^2/I<2 \times Ep/v^2$$

where a moment possessed by the rotary body is M, a hand equivalent inertial moment from the hand to the rotor of the step motor via the train wheels is I, a speed of translational motion of the timepiece by receiving an external impact is v, and a holding energy possessed by the step motor is Ep.

[0023] Alternatively, a reverse transmission preventing gear may be provided at a part of the train wheels in relation to the rotary body, in order to prevent transmission of the disturbance energy to the step motor.

[0024] The disturbance energy value in the description means the rotational energy value that occurs at the rotary body comprised of a hand, gears, pinions, and shafts fitting to the band when receiving an external impact. The disturbance energy value is a value related to imbalance caused by a degree of the unbalanced moment possessed by the rotary body and the magnitude of its inertial moment.

BRIEF DESCRIPTION OF DRAWINGS

[0025]

Fig. 1 is a schematic sectional view of a three-hand analog electronic timepiece for explaining an embodiment of the present invention;

Fig. 2 is a graph showing relations between the values of disturbance energy occurring at second hands when two types of hammer tests are conducted upon each of samples shown in Table 2, and the values of holding energy possessed by the respective step motors;

Fig. 3 is an explanatory view of normal rotational transmission motion by a reverse transmission preventing gear which is provided at a part of train wheels for rotation of hands in another embodiment of the present invention;

Fig. 4 is also an explanatory view of reverse transmission preventing motion of the same as above; and

Fig. 5 is a schematic perspective view of a conventional analog electronic timepiece showing a state in which torque is transmitted from a step motor to hands via train wheels.

BEST MODE FOR CARRYING OUT THE INVENTION

[0026] The best mode for embodying the present invention will be described hereinafter with reference to the accompanying drawings.

[0027] Fig. 1 is a schematic sectional view of a three-hand analog electronic timepiece for explaining an embodiment of the present invention, and essential components are the same as those in the conventional electronic timepiece shown in Fig. 5. Thus, the same numerals and symbols are given to the same portions in Fig.1 as those in Fig. 5.

[0028] More specifically, focusing attention on motion of a second hand 8, which is united by a second wheel 3 and a second hand shaft 18, the second hand 8 performs step movement by linking a rotor 1a of a step motor 1, a fifth wheel 2, and the second wheel 3 together in due order via pinions 11, 12. The description of third wheels 4 and thereafter will be omitted, and a minute hand 9 and an hour hand 10 are the same as those shown in Fig.5.

[0029] Numeral 21 shows a main plate, numeral 22 shows a train wheel bridge, and numeral 23 shows a dial in Fig. 1. The rotor 1a of the step motor 1, the fifth wheel 2, the second wheel 3, third wheel 4, a center wheel 5, and a minute wheel 6 (see Fig. 5) are respectively pivotally supported between the main plate 21 and the train wheel bridge 22.

[0030] An hour wheel 7 is supported between the main plate 21 and the dial 23 which is provided above the main plate 21, and is rotatably fitted outside a minute hand shalt 24 in which the second hand shaft 18 is rotatably inserted.

[0031] When this electronic timepiece receives an external impact, the second hand 8 causes disturbance energy and tends to rotate. The magnitude of the disturbance energy relates both to imbalance caused by a degree of the unbalanced moment possessed by the second band 8 to the second hand shaft 18, and to the magnitude of inertial moment (inertia) possessed by a rotary body which is comprised of the second hand 8 and train wheels from the rotor 1a of the step motor 1 to the second wheel 3 via the fifth wheel 2.

[0032] Henceforth, in this embodiment, by adding a weight 20 having a certain mass to a short hand part 8b that is on the opposite side of a indicating part 8a with respect to the second hand shaft 18 of the second hand 8, the amount of unbalanced moment of the second had 8 against the second hand shaft 18 is decreased by a counterbalance system, resulting in a reduction of the moment as of the whole rotary body, consequently, the value of a disturbance energy that occurs at the rotary body can be decreased. Therefore, if the holding energy value of the step motor 1 is set to be small, it becomes possible that the value of the disturbance energy, which the step motor 1 receives, is made smaller than that of the above holding energy.

[0033] For that purpose, first, in a conventional electronic timepiece as shown in Fig. 5, the respective moving conditions of components of the driving mechanism with mechanical movements are checked to estimate the generated energy values.

[0034] In the driving mechanism of the analog electronic timepiece which is comprised of a step motor 1, train wheels from a fifth wheel 2 to an hour wheel 7, and hands 8, 9, 10, each rotational movement information of the respective components is obtained as time information of its rotation angle. The angular acceleration derived from the above time information is multiplied by the respective inertial moments of the components to measure the produced torque value at a certain time while each of components is moving.

[0035] Of the above, the third wheel 4 and after have large reduction gear ratios, which is supposed to have minimal contributions to the driving energy. Hereinafter, attention is thus focused on motions of each component of a rotor 1a of the step motor 1 to the second hand 8 via the fifth wheel 2 and the second wheel 3 which are linked together.

[0036] The amount of driving energy used when each component moves is respectively calculated from a relation between the produced torque value while each component is moving measured by the aforementioned method and its rotation angle.

[0037] Next, the correlation is examined between the amounts of respective driving energies in the rotor 1a, the fifth wheel 2, the second wheel 3, and the second hand 8 and the respective inertial moments thereof. As a result, it is found that a idea of "rotor equivalent inertial moment" can be employed to explain the amounts of energies that are distributed to the respective components.

[0038] "Equivalent inertial moment" in this description means the idea that the inertial moments (inertia) with consideration of differences of the respective rotation speeds are added on one point to estimate a motion as of the whole rotary mechanism, since the step motor, the train wheels and the hands are all linked together to rotate as described above in a standard analog electronic timepiece. The idea is referred to as "rotor equivalent inertia" from the rotor side, and "had equivalent inertia" from the hand side.

[0039] In other words, the relation between the whole rotary mechanism and the rotor equivalent inertial moments of the respective components is expressed by the following mathematical expression.

$$J \fallingdotseq Jr+J5/36+(J4+Js)/900 \qquad (1)$$

[0040] In this expression, J represents a rotor equivalent inertial moment of the whole rotary mechanism, ad Jr, J5, J4, and Js respectively represent inertial moments of the rotor, the fifth wheel, the second wheel, and the second hand.

Each of numerical values of denominators in each term in this expression of "36" is the squared reduction gear ratio of the fifth wheel to the rotor, ad of "900" is the squared reduction gear ratio of the second wheel to the rotor.

[0041] Since the values of the squared reduction gear ratios of the third wheel ad thereafter jump further, it is clear that contributions of the third wheel and thereafter to the rotor equivalent inertial moment are negligible.

[0042] When reduction in power consumption of a gents' watch with a second band is considered as an example, the two following facts are observed, since the driving energies of the respective components are expressed as the expression (1).

[0043] One is that the smaller the rotor equivalent inertial moment J as of the whole rotary mechanism is, the more the whole driving energy decreases. The other is that contributions of the respective components to the rotor equivalent inertial moment J are different from one another, and a variation in inertial moment Js of the hand has little influence on a variation of J.

[0044] In other words, focusing on driving of the second hand, the facts show that when the driving energy value is more than a designed value, the smaller the rotor equivalent inertial moment J possessed by the components is, the more the whole driving energy can lessen.

[0045] Next, the holding energy values possessed by various step motors are estimated. Conventionally, a balance weight is hung from the second hand part and then a holding torque is measured from the weight with which the second hand can start to move, on the basis of which the holding energy value is estimated. This method, however, can not accurately estimate owing to the influence of friction and a fitting state.

[0046] Hence, using a method similar to the aforementioned method for measuring the produced energy value, rotational information of the rotor of the step motor during free rotation (during rotation under no loading) is obtained as time information of the rotation angle. On the basis of the above information, rotational information of the holding energy value is obtained by calculating the moving energy value of the rotor at a rotational position, on the basis of which the holding energy value is then estimated.

[0047] On the basis of the above results, a rotor, a fifth wheel, and a second wheel (a third wheel and thereafter are omitted) which are the next smaller size compared to the components of the hand rotational mechanism designed for a conventional gents' watch, are fabricated to confirm the effects thereof. The values of the inertial moments, the driving energy and the holding energy are shown in Table 1 with those of the conventional watch.

[0048] E—11, E—12, and E—13 in this table respectively mean $\times 10^{-11}$, $\times 10^{-12}$, and $\times 10^{-13}$. Note "←" means being the same as in the box in the left-hand side. These expressions are also applied to Table 2 and Table 3, which are shown later.

[0049] It is apparent from Table 1 that both values of the inertial moments Js of the second hands are the same, since the second hand of the newly made electronic watch is the same as that of the conventional watch, and that the value of the rotor equivalent inertial moment J considerably decreases in the newly made electronic watch and therewith the driving energy indicates 136 nJ (nanojoule) which is less than 1/3 of 435 nJ which is the value of the conventional watch.

[0050] As described above, the second hand is driven by a combination of components which are the next smaller size than those of the conventional watch and the same second hand as that of the conventional watch, resulting in the hand moving as well as the conventional one as expected.

[0051] Furthermore, when a minute hand and an hour hand are also attached to move, the moving states are not different from the conventional ones.

[0052] The holding energy value of the newly made step motor is 154 nJ (nanojoule), which is less than 1 / 2 as compared with 334 nJ of the conventional one, and in addition to the reduction of the rotor equivalent inertial moment J, the input energy which is required to drive the second hand for 1 step substantially decreases from 1450 nJ of the conventional one to 630 nJ.

[0053] It is consequently clear that the use of the hand rotary mechanism as described above enables substantial reduction in power consumption, while realizing the same moving function as the conventional one.

[0054] However, since the holding energy value becomes 154 nJ which is less than 1/2 as compared with 334 nJ of the conventional one, the hand in this state can not stand a disturbance energy occurring on receiving an external impact, which causes a had-skip phenomenon. As measures against the above, in this embodiment, the weight 20 is added to the short hand part 8b of the second hand 8 as shown in Fig. 1, to lessen the moment of the second hand 8 as of the rotary body by a counterbalance system.

[0055] The second hand of a gents' watch normally has an inertial moment of the order of 2.1×10^{-11} kg · m^2 and a moment of the order of 2.7×10^{-9} kg · m.

[0056] In the embodiment shown in Fig. 1, the weight 20 having a certain inertial moment is provided as a counterbalance on the short hand part 8b of the second hand 8, to correct imbalance of the moment with respect to the second hand shaft 18, and to reduce a disturbance energy occurring at the second hand part, in order to check whether a hand-skip phenomenon can be prevented.

[0057] To this end, hammer tests in conformity to ISO 1413 are carried out to check the presence or absence of a hand-skip phenomenon by actually giving an external impact to each sample of electronic watches.

[0058] A gents' electronic watch using a normal second hand is designated as Sample 1, and then Sample 2 to 8 of electronic watches, in which the moment correction ratios are gradually increased by elongating the length of the short hand part of the second hand by degrees. The moments of the second hands, the inertial moments (inertia) thereof, the values of the hand equivalent inertial moments, the corrective ratios to Sample 1, which the respective samples have, and the presence or absence of a hand-skip phenomenon as results of the hammer tests are shown in Table 2.

[0059] It is noted that the shown' values are results of giving a normal external impact energy in the hammer test I (dropping a hammer onto the sample from the height of 30 cm), and of giving an external impact energy twice as much as that in ,the hammer test I in the hammer test II (dropping the hammer onto the sample from the height of 63 cm). The hammer tests are carried out ten tunes for each condition, and then as results of the tests, X for when a hand-skip occurs at every time, Δ for when it sometimes occurs , and ◯ for when it never occurs, are filled in boxes corresponding to respective tests in Table 2.

[0060] As is obvious from Table 2, a hand-skip phenomenon can not be completely prevented in Sample 1 having no counterbalance even in the hammer test I. In contrast to that, it is shown that when the moment correction ratio is made more than 7 % by adding a weight having a certain inertial moment to the short hand part of the second hand (by increasing in length of the short hand part in this case), a hand-skip phenomenon can be surely prevented against an external impact

[0061] The weight 20 which is added to the short hand part of the second hand to counterbalance to the degree as above is just ,a minute item, which can be realized without spoiling the appearance of the conventional watch. It is noted that the value of the inertial moment Js of the second hand slightly increases by adding the weight 20, but the moving condition stays unchanged, since the influence by the weight 20 to the rotor equivalent inertial moment J is negligible as is obvious from the expression (1).

[0062] Next, the magnitudes of disturbance energies occurring at the second hand parts of samples 1 to 8 listed in Table 2 on receiving external impacts are estimated, and then it is attempted to compare these with the holding energy 154 nJ which is possessed by the step motor in the newly made electronic watch shown in Table 1.

[0063] The occurring mechanism of the disturbance energy, which occurs on receiving an external impact due to the degree of unbalanced moment possessed by the second hand, is considered to derive the following mathematical expression.

$$E=(v^2/2) \times (M^2/I) \qquad (2)$$

[0064] In the above expression, E represents the value of a disturbance energy which occurs at the second hand part, v represents a speed of the watch when it performs translational motion by receiving an external impact, M represents a moment possessed by the second hand, and I represents a band equivalent inertial moment.

[0065] The hand equivalent inertial moment I is the equivalent inertial moment, from the hand side, of the whole rotary body including train wheels for transmission of torque between the band and the rotor of the step motor, which is obtained from the following mathematical expression.

$$I=J4+Js+25 \cdot J5+900 \cdot Jr \qquad (3)$$

[0066] In this expression, Js, J4, J5, and Jr respectively represent inertial moments of the second hand, the second wheel, the fifth wheel, and the rotor, and each numerical value of "25" is the squared speed increasing ratio of the fifth wheel from the second hand side, and of "900" is the squared speed increasing ratio of the rotor from the second hand side.

[0067] Next, the correlation between the holding energy Ep which the step motor retains and the disturbance energy E which is derived from the expression (2) is shown in Fig. 2, in addition to the results of a hand-skip phenomenon by the hammer tests I, II shown in Table 2.

[0068] In Fig. 2, round black dots and square black dots respectively represent values of disturbance energies in the hammer tests I, II shown in Table 2, and numerals marked near the respective dots are sample numbers in Table 2. A broken line shows a level where the holding energy Ep possessed by the step motor is 154 nJ shown in a case of the newly made electronic watch in Table 1.

[0069] From the results of Table 2 and Fig. 2, it turns out that a hand-skip phenomenon can be prevented in a range where the following mathematical expression is satisfied.

$$Ep > E=(v^2/2) \times (M^2/I) \qquad (4)$$

As is clear from the results of the hammer tests in Table 2, the holding range is difficult to explicitly define due to the existence of a region where the results thereof are △ depending on conditions, however, the above expression (4) is probably a guide from these results of the tests.

[0070] Actually, a holding energy operates including friction losses in the train wheels. When the above energy is Eq, $Eq \fallingdotseq Ep + 100$ nJ , as shown by a two-dotted chain line in Fig. 2, in the structure of the step motor and the train wheels used in these hammer tests. Accordingly, no hand-skip phenomenon actually occurs on Samples 2 to 8, since $E < Eq$ in each case of Samples 2 to 8 in the impact test I as shown in the test results shown in Table 2.

[0071] This means that a moment M possessed by a second hand, a hand equivalent inertial moment I, a speed v when a the timepiece receives an external impact to perform translations, and a holding energy Ep possessed by a step motor, which conventionally seemed to be completely different parameters, correlate with one another, and at least in a range ($M^2/I < 2 \times Ep/v^2$) where the expression (4) is satisfied the hand is surely held.

[0072] Conventionally, restrictions are imposed on conditions of use for hands only by a range where a moment is established from the results of the hammer test actually carried out on the set step motor. The range where the hand needs to satisfy the conditions is determined in advance by substituting each value of the parameters in the expression (4), which achieves holding of the hand within this range.

[0073] In the aforementioned embodiment of the present invention, it is found that the second hand can be held if more than 7 % of moment is corrected to imbalance of the moment possessed by the second hand.

[0074] However, since decoration is added to the hand in practice, the inertial moment and the moment are not unconditionally determined and so are distributed in a certain range. As a measure to that, once the above hand is counterbalanced on the assumption that the moment correction ratio is the largest in a range where the expression (4) is satisfied, the same components as those of the original one can be used for various hands.

[0075] In the aforementioned embodiment, the weight 20 having a certain inertial moment is added to the short had part 8b of the second band 8 as a counterbalance (including the short had part that is lengthened or thickened). However, as measures same as above, a weight may be added at least to a part of the second wheel 3 and the pinion 13 which constitute the train wheels between the second hand 8 ad the rotor 1a shown in Fig. 1, at positions corresponding to the short hand part 8b of the second hand 8 with respect to each rotation axis.

[0076] Consequently, the moment of the whole rotary body including the second hand 8 is reduced, which enables the value of the disturbance energy that the step motor receives to be less than the holding energy value.

[0077] The second hand 8, the second wheel 3, the pinion 13, and the second hand shaft 18 are linked together to move, in which the unbalanced amount can be thus controlled by each of them separately or by a combination of two or more out of them As a means for controlling the moment, instead of adding a weight, formation of a thin part, a through hole, or a notch at least in a part of the rotary body comprised of the second hand 8, the second wheel 3, the pinion 13, and the second hand shaft 18, to lessen the moment as of the whole rotary body, can be employed.

[0078] Alternatively, at least a part of rotary members (wheels and the like) of the rotary body can be formed with a combination of members with different specific gravities from each other in order to lessen the moment as of the whole rotary body.

[0079] In these cases, the resultant disturbance energy value, that is, the value of the disturbance energy which the step motor receives, can be also made smaller than the holding energy value.

[0080] Furthermore, although the aforementioned embodiment is described in a case of the second hand as an example, the same idea can be also employed to the minute hand and the hour hand.

[0081] More specifically, when a hand to be driven is known, the driving energy value which is derived from driving conditions of the hand is first estimated, and components of a rotary body including train wheels are then designed in such a manner to have a rotor equivalent inertial moment J as small as possible while satisfying the estimated value.

[0082] Consequently, the above had is counterbalanced in such a manner as to make the disturbance energy value smaller than the holding energy value possessed by the step motor, thereby a reduction in size and a substantial decrease in power consumption are possible while satisfying the watch requirements of driving and holding of the hand at the same level as of the conventional one. Application of the present invention to a lady's watch can realize a watch which has a smaller size and a less power consumption than the conventional one, and can also cope with various designs.

[0083] Next, another embodiment of the present invention will be described with reference to Fig. 3 and Fig. 4.

[0084] In this embodiment, a surface of a dial is regarded as a world map, not specifically shown, and a second hand, on which a member modeled on a shape of an aircraft is attached in the vicinity of the tip thereof is fabricated to express an image where the aircraft flies around above the map. The values of the inertial moments and the holding energies, which are possessed by the above second band and each component of the rotary body composed of train wheels for rotating the second band, are shown in Table 3, in addition to those of the conventional gents' watch.

[0085] The inertial moment Js of the above second had increases up to be ,about eight times as large as the conventional gents' watch due to the design added to the second hand, resulting in a fear of influence on a moving behavior. However, as is estimated from the expression (1), the increment of the rotor equivalent inertial moment J is about 10 % at the maximum, and little variation is found in the actual motion, and also there is little variation in input energy as shown in Table 3.

[0086] It is checked in another test that a hand can move with little variation in motion in the step motor used in this test, within the increment of the rotor equivalent inertial moment J up to about 100%.

[0087] The moment possessed by the second had in this embodiment is about 1.8×10^{-8} kg・m, which is about seven times as large as 2.7×10^{-9} kg・m possessed by a conventional gents' watch. On the second hand in this state, as described in the aforementioned embodiment, a hand-skip phenomenon occurs on an external impact at the same level as of the conventional one.

[0088] To prevent that, in this embodiment, a reverse transmission preventing gear is provided at a part of wheels which constitute train wheels between the second hand and the rotor of the step motor in order to prevent transmission of a disturbance energy to the step motor.

[0089] Fig. 3 and Fig. 4 are drawings for explaining a motion when the reverse transmission preventing gear is used at least with any one of a pinion 31 (corresponding to any one of the pinions 11, 12 in Fig. 5) and a gear 32 (corresponding to the fifth wheel 2 or the second wheel 3 in Fig. 5) which constitute train wheels between the second bad and the rotor of the step motor in the train wheels structure of an analog three-hand electronic timepiece.

[0090] A force is normally transmitted by rotation of the pinion 31 in the A direction indicated by an arrow as shown in Fig. 3 to rotate the gear 32 in the B direction indicated by an arrow. The above relation continues from the rotor to the fifth wheel, the second wheel, the third wheel, and so on in due order to thereby transmit the force efficiently.

[0091] On the other hand, when the watch main body receives an external impact, a torque caused by the disturbance energy occurring at the second hand part acts on the gear 32 in order to transmit the torque to the pinion 31. The pinion 31 and the gear 32, however, mesh and push against each other at the point a and the point b as shown in Fig. 4, so that both of them can not rotate. Therefore, the torque of the gear 32 in the C direction indicated by a arrow, which is opposite to the direction of a normal transmission of force, is not transmitted to the pinion 31.

[0092] In order to hold the second hand, a reverse transmission preventing gear may be used at least at any one place of the pinion of the rotor and the fifth wheel, and the pinion of the fifth wheel and the second wheel. It is noted that a case where the gear 32 rotates to the left when receiving a external impact is explained in Fig. 4, and transmission of the force is prevented similarly to the above in a case of rotating to the right.

[0093] Employment of this mechanism enables a hand-skip phenomenon to be prevented even when the holding energy value possessed by the step motor is smaller than the disturbance energy value. Consequently, even when a hand which has a inertial moment ad a moment larger than those of the conventional one is used, the timepiece requirements of driving and holding of the bad can he satisfied at the same level as of the conventional one, in a similar manner to the aforementioned embodiment. This effect is checked by actually carrying out a hammer test in conformity to ISO 1413 upon a finished timepiece equipped with an hour hand, a minute hand and a second hand.

[0094] Furthermore, it is likely that a rotational energy is also added to a timepiece with the translational energy as described above by a external impact, to which a shock test is performed to check that there occurs no inconvenience.

[0095] The above shock test refers to a method of testing in consideration of a rotational impact, which is caused by placing a timepiece in a arbitrary orientation in an empty box and allowing it to fall freely from a predetermined height. It is required that there is no displacement of hands before and after the test.

[0096] Under normal use conditions, a big rotational impact is not given to a timepiece body, therefore there seems to be no problem if it passes the hammer tests.

[0097] In the two aforementioned embodiments, while effects of a counterbalance provided by adding a weight and the like ad of a reverse transmission preventing gear are described, using both mechanisms together produces other effects.

[0098] More specifically, the value of the disturbance energy occurring at the hand is quite small and does not produce a force which achieves a great change in train wheels due to the counterbalance mechanism in a region where the external impact is small, therefore the hand is held. Moreover, with a large external impact against which the hand can not be held only by the counterbalance, the reverse transmission preventing gear mechanism prevents a force from reverse transmission.

[0099] At this time, since the disturbance energy value substantially decreases due to the counterbalance, the force acting on the pushing-out part (the point b) between the gear 32 and the pinion 31 shown in Fig. 4 decreases, resulting in no danger of shape-deterioration of the pushing-out part.

[0100] Thereby, the step motor retaining a small holding energy is reliable in use and can surely hold the hand against a wide range of impacts.

[0101] It is already assured in the description in Table 1 that there is a possibility of a sufficient reduction in power consumption in the present invention as compared with the conventional one. A further reduction in power consumption is made possible by improving efficiency by optimizing conditions of components of a step motor, reduction in moment by further reduction in size of components or by employing plastic materials, relaxing drive conditions, and so on.

[0102] A mechanism omitting the counterbalance can be employed, if it can ultimately reduce an external impact to have a disturbance energy value smaller than a holding energy value. For example, a shock absorber disposed around a module may absorb an external impact at some midpoint, or the shape and material of a hand may reduce the disturbance energy value itself. Alternatively, components may be mechanically fixed against an external impact, or a structure in which a rock system works only on detecting an external impact, may be employed.

[0103] The embodiments of the present invention can be also applied to a clock, though only a wristwatch using a step motor as an actuator is described. If anything, in the ease of a clock, an external impact is not as significant as in the case of a wristwatch, so that a holding torque value thereof may be small. A rage of the driving energy required for driving hands is estimated, in which the rotor equivalent inertial moment J is reduced, thereby the power consumption can be substantially reduced.

Table 1

	Conventional Gent's Watch	Newly Made Electronic Watch
Driving Energy (nJ)	435	136
Holding Energy (nJ)	334	154
J (kg・m^2)	1.3E-12	2.3E-13
Jr (kg・m^2)	1.1E-12	1.6E-13
J5 (kg・m^2)	6.4E-12	1.9E-12
J4 (kg・m^2)	8.0E-12	3.5E-12
Js (kg・m^2)	2.1E-11	←
Input Energy (nJ)	1450	630

Table 2

Sample No.		1	2	3	4	5	6	7	8
Moment (kg・m)		2.7E-9	2.5E-9	2.3E-9	1.9E-9	1.6E-9	1.1E-9	5.9E-10	1.6E-11
Inertial Moment of the Second Hand (kg・m^2)		2.1E-11	←	2.2E-11	2.3E-11	2.4E-11	2.6E-11	2.8E-11	3.0E-11
Hand Equivalent Inertial Moment (kg・m^2)		2.0E-10	←	←	←	2.1E-10	←	←	←
Moment Correction Rate compared to Sample 1 (%)		0	7	17	29	43	60	78	99.4
Hand-Skip	Hammer Test I	△	○	←	←	←	←	←	←
	Hammer Test II	X	←	←	△	○	←	←	←

Table 3

	Conventional Gent's Watch	Electronic Watch In The Embodiment Of The Present Invention
Holding Energy (nJ)	334	←

Table 3 (continued)

	Conventional Gent's Watch	Electronic Watch In The Embodiment Of The Present Invention
J (kg • m^2)	1.3E-12	1.4E-12
Jr (kg • m^2)	1.1E-12	←
J5 (kg • m^2)	6.4E-12	←
J4 (kg • m^2)	8.0E-12	←
Js (kg • m^2)	2.1E-11	1.6E-10
Input Energy (nJ)	1450	←

INDUSTRIAL APPICABILITY

[0104] According to the present invention, in a range where the value of the driving energy required for driving hands in a timepiece is satisfied, the equivalent inertial moment of the whole rotary body including the hands and train wheels for rotating the hands is reduced. Then the value of the disturbance energy occurring at the hands, caused by an external impact, is reduced to be smaller than the reduced holding energy value.

[0105] Thereby, a substantially lower power consumption can be achieved, and a system not requiring frequent replacement of batteries can he realized, while keeping the driving and holding performances at the same level as of the conventional one.

[0106] Conversely, when the same power is used as in the conventional one, even a had having an inertial moment which is ten times or more as compared with the conventional one is used, the same driving and holding performances at the same level as of the conventional one can be secured. Therefore, decorations and functional elements can be applied to a hand part, which can not be achieved under the conventional conditions, resulting in substantial increase of flexibility.

Claims

1. An analog electronic timepiece having: hands for indicating a time; a step motor having a holding energy for holding said hands while standing still and for generating a driving energy m such a manner as to exceed the holding energy while driving said hands; and train wheels for transmitting the movement of said step motor to said hands, wherein a weight is added, to lessen a moment of the whole rotary body, at least to a part of the rotary body including said hands and said train wheels where an external impact causes a disturbance energy which is larger than the holding energy value said step motor retains, to make the value of the disturbance energy which said step motor receives less than the holding energy value.

2. An analog electronic timepiece having: hands for indicating a time; a step motor having a holding energy for holding said hands while standing still and for generating a driving energy in such a manner as to exceed the holding energy while driving said hands; and train wheels for transmitting the movement of said step motor to said hands, wherein a thin part, a through hole, or a notch is formed, to lessen a moment of the whole rotary body, at least in a part of the rotary body including said hands and said train wheels where an external impact causes a disturbance energy which is larger than the holding energy value said step motor retains, to make the value of the disturbance energy which said step motor receives less than the holding energy value.

3. An analog electronic timepiece having: bands for indicating a time; a step motor having a holding energy for holding said hands while standing still and for generating a driving energy in such a manner as to exceed the holding energy while driving said hands; and train wheels for transmitting the movement of said step motor to said hands, wherein at least a part of the rotary members of the rotary body including said bands and said train wheels, where an external impact causes a disturbance energy which is larger than the holding energy value said step motor retains, is formed, to lessen a moment of the whole rotary body, by a combination of members with different specific gravities different from each other, to make the value of the disturbance energy which said step motor receives less than the holding energy value.

4. The analog electronic timepiece according to claim 1,

wherein M and I are set to satisfy the relation below:

$$M^2/I<2 \times Ep/v^2$$

where a moment possessed by said rotary body is M, a hand equivalent inertial moment from said hand to the rotor of said step motor via said train wheels is I, a speed of translational motion of said timepiece by receiving an external impact is v, and a holding energy possessed by said step motor is Ep.

5. The analog electronic timepiece according to claim 2,
wherein M and I are set to satisfy the relation below:

$$M^2/I<2 \times Ep/v^2$$

where a moment possessed by said rotary body is M, a hand equivalent inertial moment from said hand to the rotor of said step motor via said train wheels is I, a speed of translational motion of said timepiece by receiving an external impact is v, and a holding energy possessed by said step motor is Ep.

6. The analog electronic timepiece according to claim 3,
wherein M and I are set to satisfy the relation below:

$$M^2/I<2 \times Ep/v^2$$

where a moment possessed by said rotary body is M, a hand equivalent inertial moment from said hand to the rotor of said step motor via said train wheels is I, a speed of translational motion of said timepiece by receiving a external impact is v, and a holding energy possessed by said step motor is Ep.

7. An analog electronic timepiece having: hands for indicating a time; a step motor having a holding energy for holding said hands while standing still and for generating a driving energy in such a manner as to exceed the holding energy while driving said hands; and train wheels for transmitting the movement of said step motor to said hands, wherein a reverse transmission preventing gear is provided at a part of said train, wheels to the rotary body including said hands and said train wheels where an external impact causes a disturbance energy which is larger than the holding energy value said step motor retains, to prevent transmission of the disturbance energy to said step motor.

FIG. 1

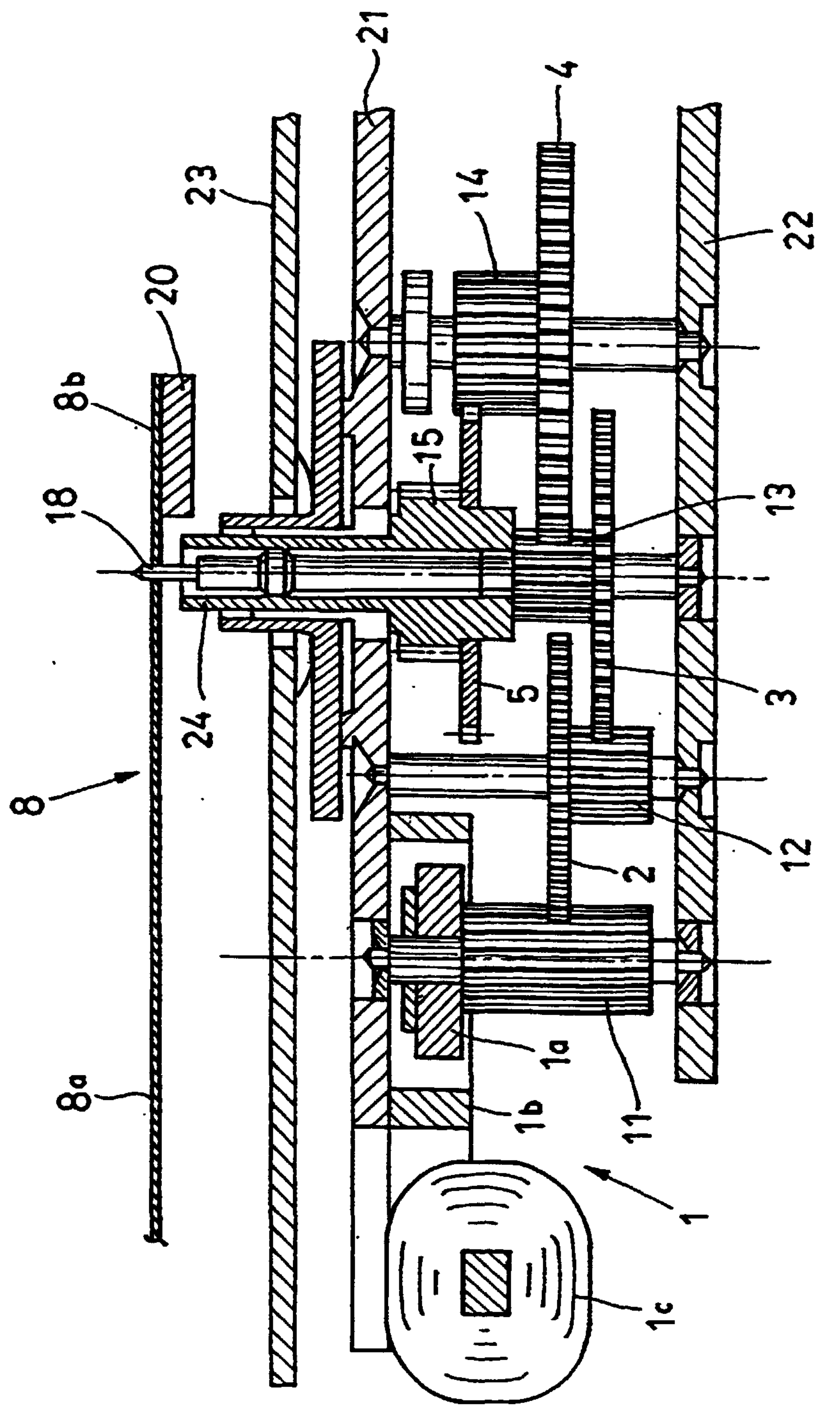
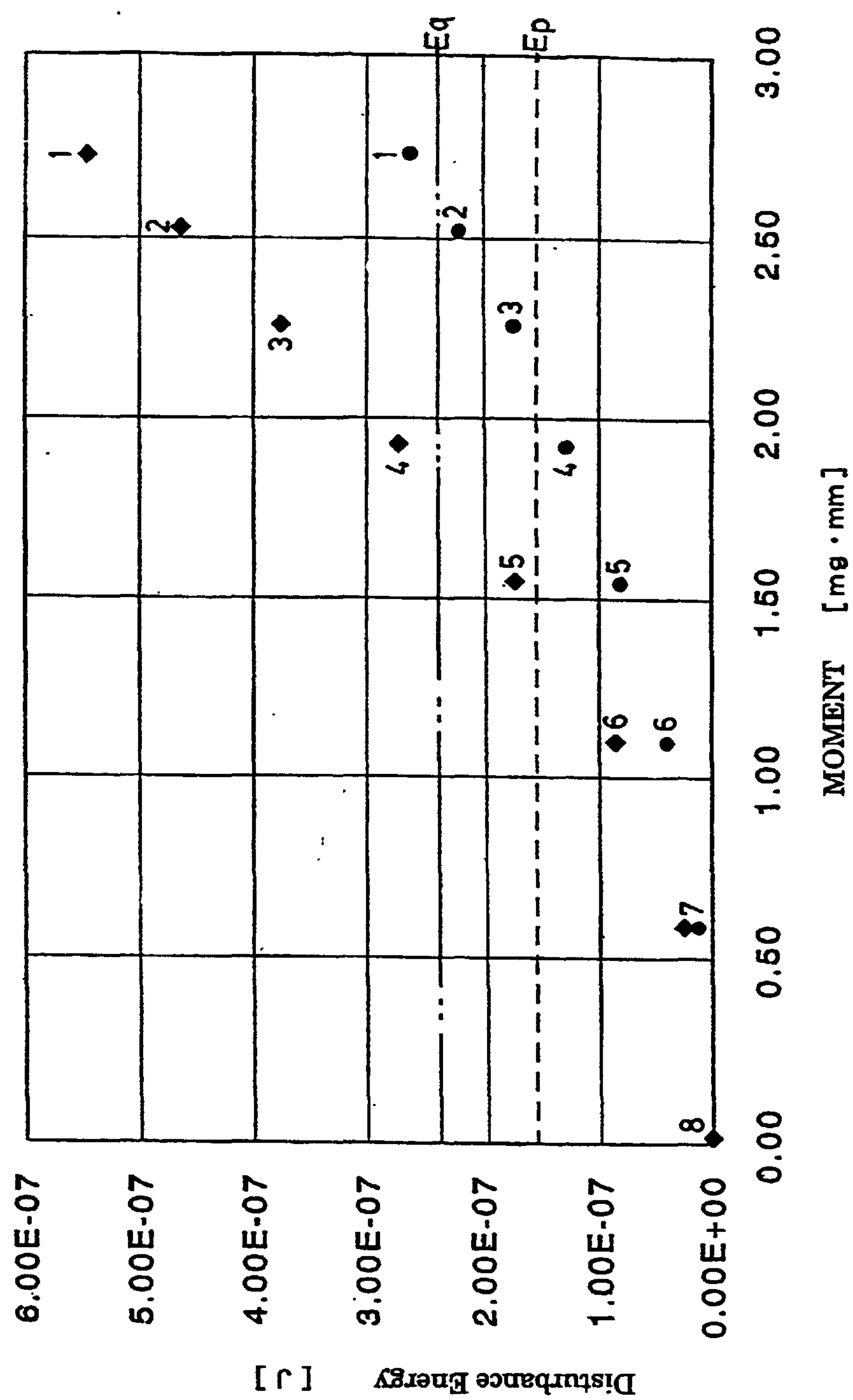


FIG. 2



Disturbance Energy [J]
6.00E-07
5.00E-07
4.00E-07
3.00E-07
2.00E-07
1.00E-07
0.00E+00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
MOMENT [mg·mm]
Eq
Ep
1
2
3
4
5
6
7
8

FIG. 3

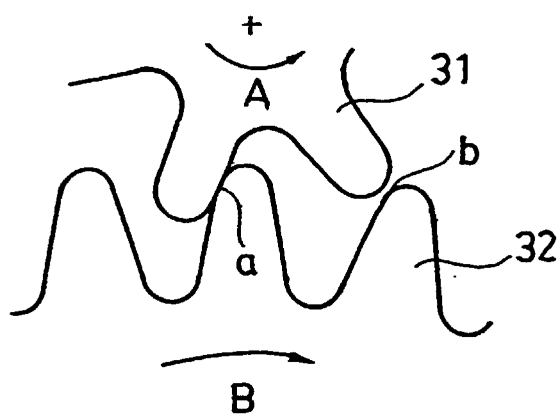


FIG. 4

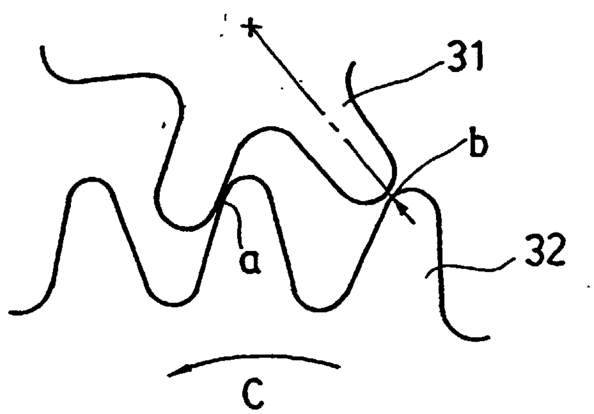
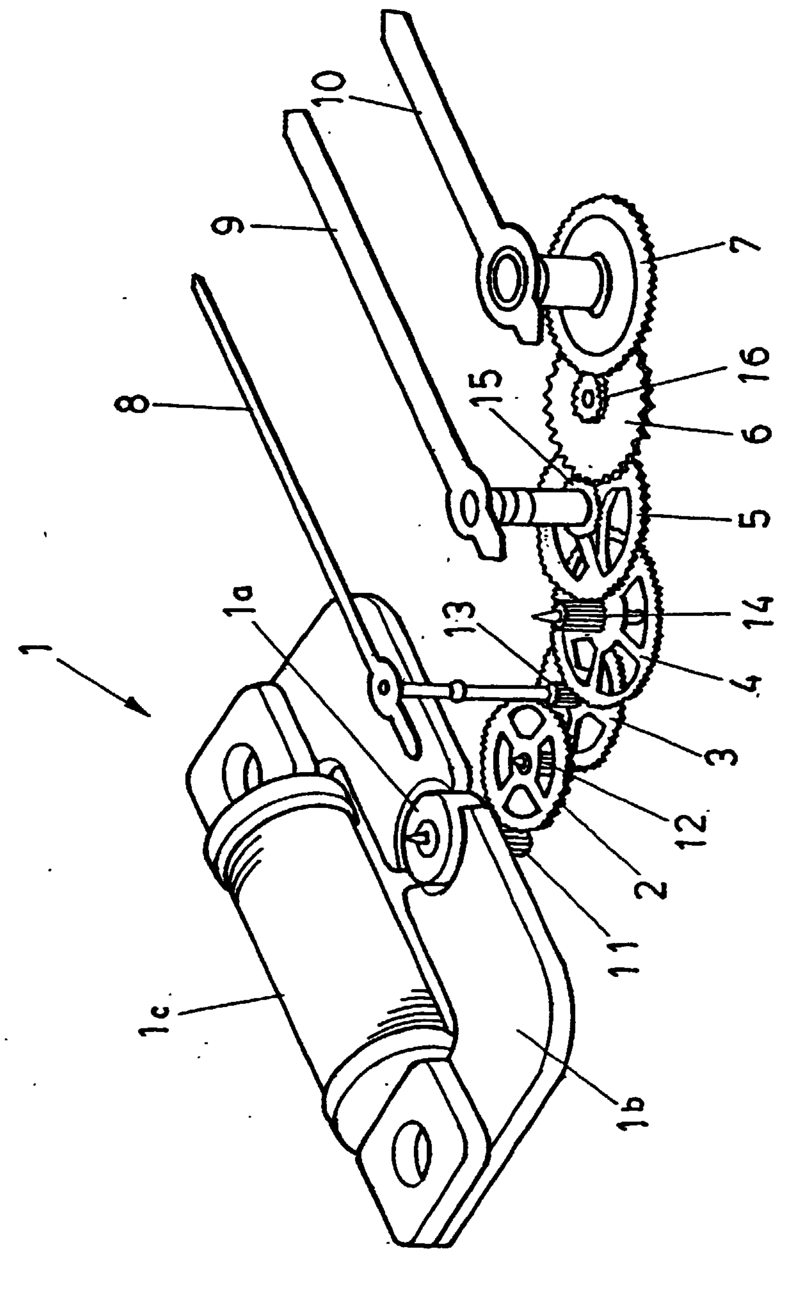


FIG. 5



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/00033

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^6 G04C3/14, G04B13/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl^6 G04C3/14, G04B13/00, G04B19/02, G04B19/04, G04B43/00, G01D7/00, G01D13/00, G12B11/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926-1996	Toroku Jitsuyo Shinan Koho	1994-1998
Kokai Jitsuyo Shinan Koho	1971-1998	Jitsuyo Shinan Toroku Koho	1996-1998

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 84056/1978 (Laid-open No. 3703/1980) (Nissan Motor Co., Ltd.), January 11, 1980 (11. 01. 80), Fig. 6	1, 2, 4, 5
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 39264/1980 (Laid-open No. 142395/1981) (Nippon Seiki Co., Ltd.), October 27, 1981 (27. 10. 81), Fig. 3	1, 2, 4, 5
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 18395/1983 (Laid-open No. 124320/1984) (Kuniharu Usui), August 21, 1984 (21. 08. 84), Claims ; page 2, line 17 to page 4, line 15 ; Figs. 1 to 3	1, 2, 4, 5

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
March 25, 1998 (25. 03. 98)	April 7, 1998 (07. 04. 98)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP98/00033

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 4-43992, A (Koen Seikan K.K.), February 13, 1992 (13. 02. 92), Figs. 1, 2 (Family: none)	2, 5
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 38181/1990 (Laid-open No. 128889/1991) (Seiko Instruments Inc.), December 25, 1991 (25. 12. 91), Fig. 4	2, 5
Y	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 86164/1985 (Laid-open No. 200953/1986) (Takahata Seiko K.K.), Drawings	2, 5
X	JP, 4-315987, A (Seiko Epson Corp.), November 6, 1992 (06. 11. 92), Claims ; Par. Nos. [0002] to [0018] (Family: none)	7
X	CD-ROM of the specification and drawings annexed to the request of Japanese Utility Model Application No. 57447/1992 (Laid-open No. 14984/1994) (Citizen Watch Co., Ltd.), February 25, 1994 (25. 02. 94), Claims ; Par. Nos. [0002] to [0017] ; Figs. 1 to 5	7
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 38181/1990 (Laid-open No. 128889/1991) (Seiko Instruments Inc.), December 25, 1991 (25. 12. 91), Fig. 4	3, 6

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