(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 158 373 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 158(3) EPC

(43) Date of publication:
28.11.2001 Bulletin 2001/48

(21) Application number: **00902140.3**

(22) Date of filing: **08.02.2000**

(51) Int Cl.[7]: **G04B 17/20**, G04B 18/02, G04C 3/04

(86) International application number:
PCT/JP00/00677

(87) International publication number:
WO 01/48566 (05.07.2001 Gazette 2001/27)

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE

(30) Priority: **24.12.1999 WOPCT/JP99/07290**
21.01.2000 WOPCT/JP00/00283

(71) Applicant: **Seiko Instruments Inc.**
Chiba-shi, Chiba-ken 261-0023 (JP)

(72) Inventors:
- **TOKORO, Takeshi Seiko Instruments Inc.**
Chiba-shi, Chiba 261-0023 (JP)
- **JUJO, Koichiro Seiko Instruments Inc.**
Chiba-shi, Chiba 261-0023 (JP)
- **HOSHINO, Masafumi Seiko Instruments Inc.**
Chiba-shi, Chiba 261-0023 (JP)

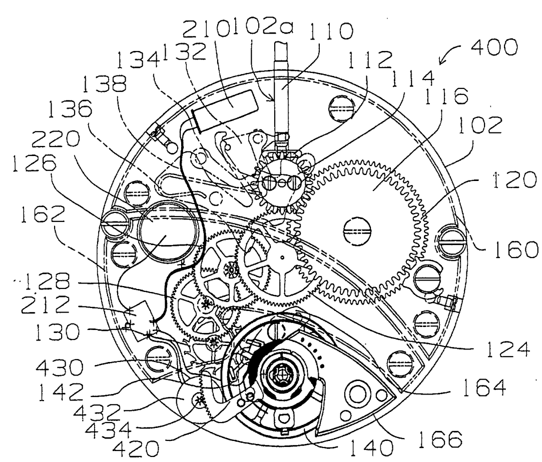
(74) Representative: **Sturt, Clifford Mark et al**
Miller Sturt Kenyon
9 John Street
London WC1N 2ES (GB)

(54) MECHANICAL TIMEPIECE WITH REGULATOR ACTUATING MECHANISM

(57) A mechanical timepiece of the present invention has a movement structured having a mainspring constituting a power source for the mechanical timepiece, a train wheel rotating due to a rotation force of the mainspring upon being rewound, an escape/speed-control device for controlling rotation of the train wheel, the escape/speed-control device including a balance with hairspring alternately repeating right and left rotation, an escape wheel and pinion rotating based on rotation of the train wheel and a pallet fork controlling rotation of the escape wheel and pinion based on operation of the balance with hairspring. The balance with hairspring includes a stud mainspring, a stud stem and a stud wheel.

The mechanical timepiece of the invention further comprises a time count section to count time having a quartz oscillator constituting source oscillation, an IC including a frequency-dividing section to input an output signal outputted due to oscillation of said quartz oscillator and output a signal concerning a time by frequency-dividing the signal, and a power source to operate said IC; a watch error section for detecting a watch error of said mechanical timepiece; and a watch-error adjusting section including a regulator operating based on a count signal counted by said time count section and an operation state signal representative of a watch error detected by said watch-error detecting section. The regulator is rotated by the motor based on a operation state signal. With this structure, the vibration period of the balance with hairspring can be varied making possible to accurately adjust the watch error of the mechanical timepiece.

FIG.1



EP 1 158 373 A1

Description

[TECHNICAL FIELD]

[0001] The present invention relates to a mechanical timepiece capable of indicating time with accuracy.

[0002] The invention relates, more specifically, to a mechanical timepiece with regulator rotation mechanism having a mechanism capable of operating the regulator to adjust a timepiece watch error.

[BACKGROUND OF THE INVENTION]

(1) Conventional Mechanical Timepiece Structure

[0003] In the conventional mechanical timepiece, as shown in Fig. 14 and Fig. 15 the mechanical-timepiece movement 1100 (mechanical body) has a main plate 1102 constituting a base plate for the movement. A hand setting stem 1110 is rotatably assembled in a hand-setting-stem guide hole 1102a of the main plate 1102. A dial 1104 (shown by the virtual line in Fig. 15) is attached to the movement 1100.

[0004] Generally, of the both sides of a main plate, the side having a dial is referred to as a "back side" of the movement and the opposite side to the side having the dial as a "front side". The train wheel assembled on the "front side" of the movement is referred to as a "front train wheel" and the train wheel assembled on the "back side" of the movement is as a "back train wheel".

[0005] The hand setting stem 1110 is determined in axial position by a switch device including a setting lever 1190, a yoke 1192, a yoke spring 1194 and a back holder 1196. A winding pinion 1112 is rotatably provided on a guide axis portion of the hand setting stem 1110. When rotating the hand setting stem 1110 in a state the hand setting stem 1110 is in a first hand-setting-stem position closest to an inward of the movement along a rotation axis direction (0 stage), the winding pinion 1112 rotates through rotation of the clutch wheel. A crown wheel 1114 rotates due to rotation of the winding pinion 1112. A ratchet wheel 1116 rotates due to rotation of the crown wheel 1114. By rotating the ratchet wheel 1116, a mainspring 1122 accommodated in a barrel complete 1120 is wound up. A center wheel and pinion 1124 rotates due to rotation of the barrel complete 1120. An escape wheel and pinion 1130 rotates through rotation of a fourth wheel and pinion 1128, third wheel and pinion 1126 and center wheel and pinion 1124. The barrel complete 1120, center wheel and pinion 1124, third wheel and pinion 1126 and fourth wheel and pinion 1128 constitutes a front train wheel.

[0006] An escapement/speed-control device for controlling rotation of the front train wheel includes a balance with hairspring 1140, an escape wheel and pinion 1130 and pallet fork 1142. The balance with hairspring 1140 includes a balance stem 1140a, a balance wheel 1140b and a stud mainspring 1140c. Based on the center wheel and pinion 1124, an hour pinion 1150 rotates simultaneously. A minute hand 1152 attached on the hour wheel 1150 indicates "minute". The hour pinion 1150 is provided with a slip mechanism for the center wheel and pinion 1124. Based on rotation of the hour pinion 1150, an hour wheel 1154 rotates through rotation of a minute wheel. An hour hand 1156 attached on the hour wheel 1154 indicates "hour".

[0007] The barrel complete 1120 is rotatably supported relative to the main plate 1102 and barrel bridge 1160. The center wheel and pinion 1124, the third wheel and pinion 1126, the fourth wheel and pinion 1128 and the escape wheel and pinion 1130 are rotatably supported relative to the main plate 1102 and train wheel bridge 1162. The pallet fork 1142 is rotatably supported relative to the main plate 1102 and pallet fork bridge 1164. The balance with hairspring 1140 is rotatably supported relative to the main plate 1102 and balance bridge 1166.

[0008] The stud mainspring 1140c is a thin leaf spring in a spiral (helical) form having a plurality of turns. The stud mainspring 1140c at an inner end is fixed to a stud ball 1140d fixed on the balance stem 1140a, and the stud mainspring 1140c at an outer end is fixed by screwing through a stud support 1170a attached to a stud bridge 1170 fixed on the balance bridge 1166.

[0009] A regulator 1168 is rotatably attached on the balance bridge 1166. A stud bridge 1168a and a stud rod 1168b are attached on the regulator 1168. The stud mainspring 1140c has a portion close to the outer end positioned between the stud bridge 1168a and the stud rod 1168b.

(2) Mechanical-Timepiece Watch Error

[0010] Generally, in the conventional representative mechanical timepiece, as shown in Fig. 16 the torque on the mainspring decreases while being rewound as the sustaining time elapses from a state the mainspring is fully wound (full winding state). For example, in the case of Fig. 16, the mainspring torque in the full winding state is about 27 g·cm, which becomes about 23 g·cm at a lapse of 20 hours from the full winding state and about 18 g·cm at a lapse of 40 hours from the full winding state.

[0011] Generally, in the conventional representative mechanical timepiece, as shown in Fig. 17 the decrease of mainspring torque also decreases a swing angle of the balance with hairspring. For example, in the case of Fig. 17, the swing angle of the balance with hairspring is approximately 240 to 270 degrees when the mainspring torque is 25 to 28 g·cm while the swing angle of the balance with hairspring is approximately 180 to 240 degrees when the mainspring torque is 20 to 25 g·cm.

[0012] Referring to Fig. 18, there is shown transition of an instantaneous watch error (numeral value indicative of timepiece accuracy) against a swing angle of a balance with hairspring in the conventional representative mechanical timepiece. Here, "instantaneous watch error" refers to "a value representative of fast or slow of a mechanical timepiece at a lapse of one day on the assumption that the mechanical timepiece is allowed to stand while maintaining a state or environment of a swing angle of a balance with hairspring upon measuring a watch error". In the case of Fig. 18, the instantaneous watch error delays when the swing angle of the balance with hairspring is 240 degrees or greater or 200 degrees or smaller.

[0013] For example, in the conventional representative mechanical timepiece, as shown in Fig. 18 the instantaneous watch error is about 0 to 5 seconds per day (about 0 to 5 seconds fast per day) when the swing angle of the balance with hairspring is about 200 to 240 degrees while the instantaneous watch error becomes about -20 seconds per day (about 20 seconds slow per day) when the swing angle of the balance with hairspring is about 170 degrees.

[0014] Referring to Fig. 19, there is shown a transition of an instantaneous watch error and a lapse time upon rewinding the mainspring from a full winding state in the conventional representative mechanical timepiece. Here, in the conventional mechanical timepiece, the "watch error" indicative of timepiece advancement per day or timepiece delay per day is shown by an extremely thin line in Fig. 19, which is obtainable by integrating over 24 hours an instantaneous watch error against a lapse time of rewinding the mainspring from the full winding.

[0015] Generally, in the conventional mechanical timepiece, the instantaneous watch error slows down because the mainspring torque decreases and the balance-with-hairspring swing angle decreases as the sustaining time elapses with the mainspring being rewound from a full winding state. Due to this, in the conventional mechanical timepiece, the instantaneous watch error in a mainspring full winding state is previously put forward in expectation of timepiece delay after lapse of a sustaining time of 24 hours, thereby previously adjusting plus the "watch error" representative of timepiece advancement or delay per day.

[0016] For example, in the conventional representative mechanical timepiece, as shown by an extreme thin line in Fig. 19 the instantaneous watch error in a full winding state is about 3 seconds per day (3 seconds fast per day). However, when 20 hour elapses from the full winding state, the instantaneous watch error becomes about -3 seconds per day (about 3 seconds slow per day). When 24 hours elapses from the full winding state, the instantaneous watch error becomes about -8 seconds per day (about 8 seconds slow per day). When 30 hours elapses from the full winding state, the instantaneous watch error becomes about -16 seconds per day (about 16 seconds slow per day).

[0017] In the conventional mechanical timepieces, the timepiece accuracy has been determined by an accuracy of operating the escape/speed-control device including a balance with hairspring to repeat right and left rotation, an escape wheel and pinion to rotate based on rotation of the train wheel and a pallet fork to control rotation of the escape wheel and pinion based on the operation of the balance with hairspring.

(3) Problem that the Invention is to Solve

[0018] Accordingly, in order to enhance the timepiece accuracy, the vibration period of the balance with hairspring must be increased. It has been impossible to manufacture an escape/speed-control device including such a balance with hairspring.

[0019] Moreover, in the conventional mechanical timepieces, there is limitation in range that the timepiece accuracy is to be improved. Consequently, there has been a problem that the limit the timepiece accuracy is to be improved is delimited.

[0020] Accordingly, the conventional mechanical timepieces have been worse in accuracy than the accuracy of the quartz-type timepieces. Consequently, the conventional timepiece's users must have corrected time indicated by the mechanical timepiece.

(4) Object of the Invention

[0021] Therefore, it is an object of the present invention to provide a mechanical timepiece extremely high in accuracy.

[0022] Also, another object of the invention is to provide an accurate mechanical timepiece that can be used over a long term.

[DISCLOSURE OF THE INVENTION]

(1) Structure of Mechanical Timepiece of the Invention

[0023] A mechanical timepiece of the present invention has a movement structured having a mainspring constituting a power source for the mechanical timepiece, a train wheel rotating due to a rotation force of the mainspring upon being rewound, an escape/speed-control device for controlling rotation of the train wheel, the escape/speed-control device including a balance with hairspring alternately repeating right and left rotation, an escape wheel and pinion rotating based on rotation of the train wheel and a pallet fork controlling rotation of the escape wheel and pinion based on operation of the balance with hairspring, the balance with hairspring including a stud mainspring, a stud stem and a stud wheel.

[0024] The mechanical timepiece of the invention comprises a time count section to count time having a quartz oscillator constituting source oscillation, an IC including a frequency-dividing section to input an output signal outputted due to oscillation of said quartz oscillator and output a signal concerning a time by frequency-dividing the signal, and a power source to operate said IC; a watch error section for detecting a watch error of said mechanical timepiece; and a watch-error adjusting section including a regulator operating based on a count signal counted by said time count section and an operation state signal representative of a watch error detected by said watch-error detecting section. By rotating the regulator based on an operation state signal in this manner, the vibration period of the balance with hairspring is varied making possible to accurately adjust the watch error of the mechanical timepiece.

[0025] In the mechanical timepiece of the invention, the power source is a primary battery, such as for example a silver battery or a lithium battery. The power source may be a solar battery, a chargeable secondary battery or a chargeable capacitor. Furthermore, the mechanical timepiece of the invention may be provided with an automatic power generation section.

[0026] Also, said watch-error adjusting section of the mechanical timepiece of the invention is preferably configured to operate said regulator with a period of from once per hour to once per day.

[0027] Also, said watch-error detecting section of the mechanical timepiece of the invention preferably includes a pallet-fork detecting piezoelectric element provided on a bank pin to detect operation of said pallet fork, and a pallet-fork signal count section to count pallet-fork detection signals outputted by said pallet-fork detecting piezoelectric element.

[0028] Also, said watch-error adjusting section of the mechanical timepiece of the invention preferably includes a regulator rotating due to rotation of an ultrasonic motor. With this structure, the regulator can be positively rotated without providing a reduction train wheel. This can accurately adjust the watch error of the mechanical timepiece.

[0029] Also, the watch-error adjusting section of the mechanical timepiece of the invention may be structured including a regulator to rotate through a reduction train wheel due to rotation of a step motor. With this structure, the regulator can be positively rotated by a simple part structure and circuit configuration. This can accurately adjust the watch error of the mechanical timepiece.

(2) Effect of Mechanical Timepiece of the Invention

[0030] In the usual analogue quartz timepiece, used are a battery, quartz, an IC, a motor, a train wheel, hands and so on. In such an analogue quartz timepiece, the energy possessed by the battery is used to operate the quartz and IC to measure time and rotate the motor to indicate time. The energy used to operate the quarts and IC to measure the IC and the energy used to rotate the motor to indicate time are in a ratio of approximately 3: 7. Accordingly, in the analogue quartz timepiece, if only the function to measure time is used, the life of the battery will increase to three times or longer. In the usual analogue quartz timepiece, because the battery life is approximately two years, if a battery having the same shape as the usual analogue quartz timepiece is used, the battery can be used for six years or longer.

[0031] Also, the usual mechanical timepiece can be used for about five years without any repair. If overhaul is made after five years from the beginning of use, it can be used further about five years. Accordingly, the usual mechanical timepiece, if overhauled once, can be used for approximately ten years.

[0032] Accordingly, in the mechanical timepiece of the invention, if a battery, quartz and IC similar to the usual analog quartz timepiece are used, there is no necessity of replacing the battery to a time when there is a need of conducting overhaul. Furthermore, in the mechanical timepiece of the invention, if the capacity of the battery is increased to decrease the power consumption of the IC, it is possible to obtain a timepiece without requiring battery replacement before the life of the mechanical structural part runs out.

[0033] Also, in the mechanical timepiece of the invention, because the timepiece operates due to a mechanical structure, even if the life of the battery runs out, there is no fear that the timepiece stops. The accuracy of time indication merely worsens than that the battery life runs out.

[0034] Incidentally, in the mechanical timepiece, if a power generator mechanism and chargeable power source is mounted, there becomes no fear that the battery life runs out.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[0035]

Fig. 1 is a plan view showing a schematic form of a surface side of a movement in a first embodiment of a mechanical timepiece of the present invention (in Fig. 1, parts are partly omitted and a bridge member is shown by a virtual line).

Fig. 2 is a fragmentary sectional view showing a schematic form of a part for controlling operation of the balance with hairspring in the first embodiment of the mechanical timepiece of the present invention.

Fig. 3 is a block diagram showing an outline of operation for controlling operation of the balance with hairspring in the first embodiment of the mechanical timepiece of the present invention.

Fig. 4 is a sectional view showing a schematic form of an ultrasonic motor in the first embodiment of the mechanical timepiece of the present invention.

Fig. 5 is a circuit diagram of a schematic structure of a drive circuit to the ultrasonic motor in the first embodiment of the mechanical timepiece of the present invention.

Fig. 6 is a plan view showing a schematic form of an ultrasonic stator in the first embodiment of the mechanical timepiece of the present invention.

Fig. 7 is a sectional view showing a schematic form of the ultrasonic stator in the first embodiment of the mechanical timepiece of the present invention.

Fig. 8 is a time chart showing the principle of controlling operation of the train wheel in the first embodiment of the mechanical timepiece of the present invention.

Fig. 9 is a schematic fragmentary plan view showing a structure of a part to detect operation of the train wheel in the first embodiment of the mechanical timepiece of the present invention.

Fig. 10 is a time chart showing the principle of controlling operation of the train wheel in a second embodiment of a mechanical timepiece of the present invention.

Fig. 11 is a flowchart showing operation of the part for controlling operation of the train wheel in the first embodiment of the mechanical timepiece of the present invention.

Fig. 12 is a plan view showing a schematic form of a surface side of a movement in the second embodiment of the mechanical timepiece of the present invention (in Fig. 12, parts are partly omitted and a bridge member is shown by a virtual line).

Fig. 13 is a block diagram showing an outline of operation for controlling operation of the balance with hairspring in the second embodiment of the mechanical timepiece of the present invention.

Fig. 14 is a plan view showing a schematic form of a surface side of a movement in a conventional mechanical timepiece (in Fig. 14, parts are partly omitted and a bridge member is shown by a virtual line).

Fig. 15 is a schematic fragmentary sectional view of the movement of the conventional mechanical timepiece (in Fig. 15, parts are partly omitted).

Fig. 16 is a graph schematically showing a relationship between a lapse of time of rewinding from full winding and a mainspring torque in the mechanical timepiece.

Fig. 17 is a graph schematically showing a relationship between a swing angle of the balance with hairspring and a mainspring torque in the mechanical timepiece.

Fig. 18 is a graph schematically showing a relationship between a swing angle of the balance with hairspring and an instantaneous watch error in the mechanical timepiece.

Fig. 19 is a graph schematically showing a relationship between a lapse of time of rewinding from full winding and an instantaneous watch error in the mechanical timepiece.

[BEST MODE FOR CARRYING OUT THE INVENTION]

[0036] Hereunder, embodiments of a mechanical timepiece of the present invention will be explained based on the drawings.

(1) Structure of Switch Device and Winding Section

[0037] Referring to Fig. 1 and Fig. 2, in a first embodiment of a mechanical timepiece of the invention, a movement 400 of the mechanical timepiece has a main plate 102 structuring a base plate for the movement. A hand-setting stem 110 is rotatably assembled in a winding-stem guide hole 102a of the main plate 102.

[0038] A dial (not shown) is attached on the movement 400 of the mechanical timepiece of the invention. The dial is provided, for example, with a 12:00 division, 3:00 division, 6:00 division and 9:00 division.

[0039] The hand-setting stem 110 has a squared portion and a guide shaft portion. A clutch wheel (not shown) is assembled on the square portion of the hand setting stem 110. The clutch wheel has a same rotation axis as a rotation axis of the hand setting stem 110. That is, the clutch wheel is provided having a squared hole and rotated based on rotation of the hand setting stem 110 by fitting the squared hole on the squared portion of the hand setting stem 110. The clutch wheel has teeth A and teeth B. The teeth A are provided in the clutch wheel at an end close to a center of the movement. The teeth B are provided in the clutch wheel at an end close to an outside of the movement.

[0040] The movement 400 is provided with a switch device to determine an axial position of the winding stem 110. The switch device includes a setting lever 132, a yoke 134, a yoke spring 136 and a setting lever jumper 136. The hand-setting stem 110 is determined in rotational axial position based on rotation of the setting lever 132. The clutch wheel is determined in rotation-axis position based on rotation of the yoke 134. The yoke 134 is to be determined at two positions in rotational direction based on rotation of the setting lever 132.

[0041] A winding pinion 112 is rotatably provided on the guide shaft portion of the hand setting stem 110. When the hand setting stem 110 in a state at a first hand setting stem 110 is positioned closest to a movement 400 inner side along the rotation axis direction (in a 0 stage), the winding pinion 112 is structurally rotated through rotation of the clutch wheel. A crown wheel 114 is assembled to rotate due to rotation of the winding pinion 112. A ratchet wheel 116 is assembled to rotate due to rotation of the crown wheel 114.

[0042] The movement 400 has as a power source a mainspring (not shown) accommodated in a barrel complete 120. The mainspring is made of an elastic material having springiness, such as iron. The mainspring is structured for rotation due to rotation of the ratchet wheel 116.

[0043] A center wheel and pinion 124 is assembled for rotation due to rotation of the barrel complete 120. A third wheel and pinion 126 is assembled rotatable based on rotation of the center wheel and pinion 124. A fourth wheel and pinion 128 is assembled rotatable based on rotation of the third wheel and pinion 126. An escape wheel and pinion 130 is assembled for rotation due to rotation of the fourth wheel and pinion 128. The barrel complete 120, the center wheel and pinion 124, the third wheel and pinion 126 and the fourth wheel and pinion 128 constitute a front train wheel.

(2) Structure of an Escapement/Governing Deice of a First Embodiment

[0044] The movement 400 has an escapement/governing device assembled therein to control rotation of the front train wheel. The escapement/governing device includes a balance with hairspring 140 to repeat right and left rotation with a constant period, an escape wheel and pinion 130 to rotate based on rotation of the front train wheel, and pallet fork 142 to control rotation of the escape wheel and pinion 130 based on the operation of the balance with hairspring 140.

[0045] Basic principles of operation of pinion 130, pallet fork 142, and hairspring 140 are same as conventional movement of mechanical timepiece.

[0046] Referring to Fig. 9, the pallet fork 142 has an entry pallet 142a provided contactable with the escape wheel and pinion 130, an exit pallet 142b provided contactable with the escape wheel and pinion 130, a pallet-fork guard pin 142c provided such that a balance-with hairspring roller jewel (not shown) enters and leaves, and a pallet-fork rod 142d.

[0047] If the balance with hairspring and roller jewel rotates leftward (counterclockwise), the roller jewel enters the pallet-fork guard pin 142c. Thereupon, the roller jewel causes the pallet fork 142 rightward (clockwise) and stops/releases it on the entry pallet 142a side. Thereupon, a locking corner of the escape wheel and pinion 130 moves to an impact surface of the entry pallet 142a. The force of the escape wheel and pinion 130 pushes up the impact surface of the entry pallet 142a and rotates the pallet fork 142 rightward (clockwise). Thereupon, the pallet-fork guard pin 142c pushes the roller jewel and rotates the roller jewel leftward (counterclockwise).

[0048] After the impact has ended, the tooth of the escape wheel and pinion 130 leaves the entry pallet 142a so that the escape wheel and pinion 130 races and the escape wheel and pinion 130 falls down. After ending the fall down of the escape wheel and pinion 130, another tooth of the escape wheel and pinion 130 hits a stop surface of the exit pallet 142b into a first halt state.

[0049] After ending the first halt state, when the roller jewel leaves the pallet-fork guard pin 142c, the pallet fork 142 causes the roller jewel to rotate leftward (counterclockwise) due to the force of the escape wheel and pinion 130. Then, the pallet-fork rod 142d contacts a first bank pin 102d of the main plate, and the pallet fork 142 ceases in rotation into a second halt state.

[0050] Then, the balance with hairspring 140 rotates leftward (counterclockwise) and freely vibrates.

[0051] Next, when the balance with hairspring 140 reaches a maximum deflection angle position, the balance with hairspring 140 rotates rightward (clockwise) and the roller jewel also rotates rightward (clockwise).

[0052] Thereupon, the roller jewel contacts the pallet-fork guard pin 142c and the pallet fork 142 rotates leftward (counterclockwise). Thereupon, this is halted and released on the side of the exit pallet 142b and repeats the same operation as that of the exit pallet 142b on the entry pallet 142a side.

(3) First-Embodiment Train wheel Structure

[0053] Referring again to Fig. 1 and Fig. 2, based on rotation of the second wheel and pinion 124, a cannon pinion (not shown) simultaneously rotates. A minute hand (not shown) mounted on the cannon pinion is structured to indicate "minute". The canon pinion is provided with a slip mechanism having a predetermined slop torque to the second wheel and pinion 124.

[0054] Based on rotation of the cannon pinion, minute wheel (not shown) rotates. Based on rotation of the minute wheel, an hour wheel (not shown) rotates. An hour hand (not shown) mounted on the hour wheel is structured to indicate "hour".

[0055] The barrel complete 120 is supported rotatable relative to the main plate 102 and barrel bridge 160. The second wheel and pinion 124, third wheel and pinion 126, fourth wheel and pinion 128 and escape wheel and pinion 130 is supported rotatable relative to the main plate 102 and train wheel bridge 162. The pallet fork 142 is supported rotatable relative to the main plate 102 and pallet bridge 164.

(4) First-Embodiment Balance-with-Hairspring Structure

[0056] The balance with hairspring 140 is supported rotatable relative to the main plate 102 and balance bridge 166. That is, an upper tenon of the balance stem 140a is supported rotatable relative to a balance upper bearing fixed on the balance bridge 166. The balance upper bearing includes a balance upper hole jewel and a balance upper cap jewel. The balance upper hole jewel and balance upper cap jewel is made of an insulation material such as ruby. The balance with hairspring 140 includes a balance stem 140a, a balance wheel 140b and mainspring 140c.

[0057] A lower tenon of the balance stem 140a is supported rotatable relative to a balance lower bearing fixed on the main plate 102. The balance lower bearing includes a balance lower hole jewel and a balance lower cap jewel. The balance lower hole jewel and balance lower cap jewel is made of an insulation material such as ruby.

[0058] The stud mainspring 140c is a thin leaf spring in a spiral form (helical form) having a plurality of turns. An inner end of the stud mainspring 140c is fixed to a stud ball fixed on the balance stem 140a, and an outer end of the stud mainspring 140c is screw-fixed through a stud holder attached to a stud bridge 166a rotatably fixed on the balance bridge 166. The balance bridge 166 is made of a metal conductive material such as brass. The stud bridge 166a is made of a metal conductive material such as iron.

[0059] The stud mainspring 140c expands and contracts radially of the stud mainspring 140c depending on a rotation angle of the balance with hairspring 140 in rotation. For example, in a state shown in Fig. 1, when the balance with hairspring 140 rotates clockwise, the stud mainspring 140c contracts in a direction toward a center of the balance with hairspring 140. Contrary to this, when the balance with hairspring 140 rotates counterclockwise, the stud mainspring 140c expands in a direction away from the center of the balance with hairspring 140.

[0060] The stud mainspring 140c is made of an elastic material having springiness such as "elinvar". That is, the stud mainspring 140c is made of a metal conductive material.

(5) First-Embodiment Regulator Structure and operation

[0061] A regulator 420 is rotatably mounted on the balance bridge 166. A rotation center of the regulator 420 is the same as a rotation center of the balance with hairspring 140. The regulator 420 includes a regulator body 422, a regulator gear 424, a stud bridge 426 and a stud rod 428. A bore provided in a rotation center of the regulator body 422 rotatably fit on an outer periphery of the upper bearing of the balance with hairspring 140. The regulator gear 424 is a partly teethed gear which is provided on the outer periphery of the regulator body 422 (gear structured having teeth provided not on the entire outer periphery but in part of the outer periphery, see Fig. 1).

[0062] The stud mainspring 140c at a portion near the outer periphery is supported between the stud bridge 426 and the stud rod 428. Consequently, by rotating the regulator 420 and determining a position of the stud bridge 426 and stud rod 428, an effective length of the stud mainspring 140c is determined. If an effective length of the stud mainspring 140c is determined, a rotation period of the balance with hairspring 140 is determined, determining a watch error of the mechanical timepiece.

(6) First-Embodiment Ultrasonic Motor Structure and Operation

[0063] Next, explanation will be made on the structure and operation of a ultrasonic motor.

[0064] An ultrasonic motor 410 is mounted on the main plate 102. For example, the ultrasonic motor 410 at an outer periphery is fitted in a ultrasonic-motor assembling bore of the main plate 102.

[0065] Referring to Fig. 2 and Fig. 4, the ultrasonic motor 430 has a housing 432, an ultrasonic rotor 434, an ultrasonic-motor pinion 436 and an ultrasonic-motor spring 438. An ultrasonic stator 442 is fixed on an ultrasonic-stator shaft 444. The ultrasonic-stator shaft 444 is fixed to the housing 432. The ultrasonic-motor pinion 436 is integrally formed with the ultrasonic rotor 434. Consequently, by rotating the ultrasonic motor 434, the ultrasonic-motor pinion 436 rotates. The regulator gear 424 is in mesh with the ultrasonic-motor pinion 436. Consequently, by rotating the ultrasonic rotor 434 and ultrasonic-motor pinion 436, the regulator gear 424 rotates.

[0066] A plurality of protrusions (comb teeth) 817 for magnifying the displacement of the ultrasonic stator 442, and delivering drive force from the ultrasonic stator 442 to the ultrasonic rotor 434 are provided in a surface of the ultrasonic stator 442. Due to an elastic force of the ultrasonic-motor spring 438, the ultrasonic rotor 434 is pushed onto the protrusions (comb teeth) 817 of the ultrasonic stator 442.

[0067] Referring to Fig. 4 and Fig. 5, the ultrasonic stator 442 structuring a vibrator for the ultrasonic motor 430 is bonded, in one surface, with a piezoelectric element 802 formed with two sets of electrode groups 803a, 803b comprising a plurality of electrodes. An oscillation drive circuit 825 is connected to the electrode groups 803a, 803b of the piezoelectric element 802. An inverter 812 plays an role as an inverter power amplifier to invert and amplify an electric signal as oscillation information, by the electrodes 803c formed on one surface and the other surface formed with the electrode groups 803a, 803b of the piezoelectric element 802 or the ultrasonic stator 442. A resistor 813 is connected in parallel with the inverter 812 to stabilize an operation point of the inverter 812.

[0068] An output terminal of the inverter 812 is connected to input terminals of two sets of buffers 811a, 811b through a resistor 814. Output terminals of the two buffers 811a, 811b are respectively connected to the electrode groups 803a, 803b of the piezoelectric element 802. A capacitor 815 at one end is connected to an input terminal of the inverter 812, and the capacitor 816 at one end is connected to an output terminal of the inverter 812 through the resistor 814. The capacitors 815, 816 at the other ends are ground to perform phase adjustment inside the oscillation drive circuit 825.

[0069] The inverter 812 and the buffers 811a, 811b respectively have control terminals together with the input terminals and output terminals, which are an inverter and buffers of a tri-state configuration capable of bringing the output terminal to a high impedance state depending on a signal inputted to the control terminal.

[0070] A forward-reverse signal generating means 820 outputs to a switch circuit 826 a forward/reverse signal to set a rotation direction of the ultrasonic rotor 434 of the ultrasonic motor 430. The output terminals of the switch circuit 826 are respectively connected to the tristate buffer 811a, 811b of the oscillation drive circuit 825 and to the control terminal of the tri-state inverter 812, to make one of the tri-state buffers 811a, 811b function as a usual buffer on the basis of the output signal of the forward-reverse signal generating means 820, and the output terminal of the other buffer in a high impedance state for disabling.

[0071] The ultrasonic stator 442 is driven by a tri-state buffer to function as a usual buffer selected by an output signal of the switch circuit 826. The ultrasonic stator 422 is driven only by a tri-state buffer allowed to function as a usual buffer by the switch circuit 826. If the tri-state buffer allowed to function as a usual buffer is changed by the switch circuit 826, the ultrasonic rotor 434 of the ultrasonic motor 430 is inverted in rotational direction.

[0072] By an output signal from the switch circuit 826 outputted based on an output from the forward-reverse signal generating means 820, the tri-state inverter in the output terminal can be brought in a high impedance state. When the tri-state inverter is disabled, the tri-state buffers 811a, 811b are both disabled to enable to stop the rotation of the ultrasonic rotor 434 of the ultrasonic motor 430.

[0073] Referring to Fig. 6 and Fig. 7, the disc-formed ultrasonic stator 442 is bonded, in its one flat surface, with a disc-formed piezoelectric element 802 through adhesion, thin-film formation or the like. Two-wavelength vibration waves (e.g. standing waves) are oscillated circumferentially of the ultrasonic stator 442 to rotationally drive the ultrasonic rotor 434. The piezoelectric element 802 is circumferentially formed, in its one flat surface, with alternate 8-divided electrodes that are 4 times relative to the number of waves to provide a first electrode group 803a and a second electrode group 803b, and processed with polarization (+) and (-) as shown in Fig. 6 and 7.

[0074] The first electrode group 803a is constituted by electrodes a1, a2, a3, a4. The electrodes are short-circuited by a first connecting means 814a. The second electrode group 803b is constituted by electrodes b1, b2, b3, b4. The electrodes are short-circuited by a second connecting means 814b.

[0075] (+), (-) in Fig. 6 and Fig. 7 shows a direction of polarization, which is each polarized by applying a positive electric field and negative electric field to a bonding surface side of the piezoelectric element 802 with the ultrasonic stator 442.

[0076] The protrusions (comb teeth) 817 for magnifying the displacement of the ultrasonic stator 442 and conveying drive force from the ultrasonic stator 442 to the ultrasonic rotor 434 are provided in the vicinity of every other boundary of the electrodes.

[0077] A high frequency voltage generated by the oscillation drive circuit 825 is applied to either one of the electrode group 803a or 803b thereby driving the ultrasonic stator 442. The rotational direction of the ultrasonic rotor 434 of the ultrasonic motor 430 is switched depending upon which electrode group the ultrasonic stator 442 is driven by.

[0078] Although the ultrasonic motor used in the invention is preferably driven by the above structure of the drive circuit, piezoelectric element and ultrasonic stator, it is to be driven by other structure.

(7) First-Embodiment Time-Count Section Structure and Operation

[0079] Next, explanation will be made on the structure and operation of a time-count section of the mechanical timepiece of the invention.

[0080] Referring to Fig. 3, a quartz oscillator 210 constitutes source oscillation for a circuit to count time. An IC 212 includes a frequency-dividing circuit 214, a corrected-pulse comparator circuit 216, a ultrasonic-motor drive circuit 468, a waveform correcting circuit 332 and a detection-signal frequency dividing circuit 334.

[0081] The frequency-dividing circuit 214 inputs an output signal outputted by oscillation of the quartz oscillator 210 and outputs a signal concerning a time (see (2) of Fig. 8). The waveform correcting circuit 332 modifies a waveform of a detection signal outputted by a watch-error detecting section. The detection-signal frequency-dividing circuit 334 divides a frequency of a corrected detection signal outputted by the waveform correcting circuit 332.

[0082] The corrected-pulse comparator circuit 216 compares between a frequency-divided signal outputted by the frequency-dividing circuit 214 (see (2) of Fig. 8) and a frequency-divided detection signal outputted by the detection signal frequency dividing circuit 334 (see (1) of Fig. 8). The ultrasonic motor drive circuit 468 outputs a ultrasonic-motor drive signal for driving the ultrasonic motor 430 to the ultrasonic motor 430, based on a signal outputted by the corrected-pulse comparator circuit 216.

[0083] A battery 220 constitutes a power source to operate the IC 212. The quartz oscillator 210, the frequency-dividing circuit 214 in the IC 212 and the battery 220 constitute a time count section for counting time.

(8) First-Embodiment Watch-Error Detecting Section Structure and Operation

[0084] Next, explanation will be made on the structure and operation of a watch-error detecting section of the mechanical timepiece of the invention.

[0085] Next, referring to Fig. 1, Fig. 2, Fig. 3 and Fig. 9, the train wheel 224 is rotated by the mainspring 222 as a power source. By the rotation of the train wheel 224, the minute hand 226 structurally indicates "minute" and the hour hand 228 indicates "hour". The minute hand 226 is fixed on the second wheel and pinion 124. The second wheel and pinion 124 is structured to rotate once per hour. By the rotation of the train wheel 224, the escape wheel and pinion 130 rotates. The pallet fork 142 controls the rotation of the escape wheel and pinion 130 based on the operation of the balance with hairspring

140.

[0086] An pallet-fork detecting piezoelectric element 336 is fixed to a first bank pin 102d of the main plate 102. Consequently, the ankle rod portion 142d is structured to contact the pallet-fork detecting piezoelectric element 336. At the instance that the pallet-fork rod portion 142d hits the pallet-fork detecting piezoelectric element 336, the pallet-fork detecting piezoelectric element 336 generates a voltage (see (4) of Fig. 10).

[0087] The pallet-fork detecting piezoelectric element 336 constitutes a watch-error detecting section 330 to detect a rotational operation state of the train wheel. When the pallet-fork rod portion 142d hits the pallet-fork detecting piezoelectric element 336, a detection signal structurally enter the IC 212. Because the balance with hairspring 140 vibrates at 3 Hertz, the watch-error detecting section 330 at 3 Hertz outputs a detection signal.

[0088] The waveform correcting circuit 332 is configured to input therein a detection circuit outputted by the pallet-fork detecting piezoelectric element 336, and shape a waveform thereof and output a corrected signal to the detection-signal frequency dividing circuit 334.

[0089] The detected-signal frequency dividing circuit 334 is configured to frequency-divide the corrected signal and output a corrected frequency-divided signal to the corrected-pulse comparator circuit 216.

[0090] Referring to Fig. 3, the corrected-pulse comparator circuit 216 is configured to compare between a period of one hour measured by the escape/speed-control device and a period of one hour measured by the IC 212.

[0091] The watch-error detecting section 330 outputs to the IC 212 a detection signal of one-hour period measured by the escape/speed-control device including the escape wheel and pinion 130, pallet fork 142 and balance with hairspring 140 due to hit of the pallet-fork rod portion 142d to the pallet-fork detecting piezoelectric element 336.

[0092] That is, the watch-error detecting section 330 includes the pallet-fork rod portion 142d and the pallet-fork detecting piezoelectric element 336.

(9) First-Embodiment Watch-Error Adjusting Section Structure and Operation

[0093] Next, explanation will be made on the structure and operation of a watch-error adjusting section of a mechanical timepiece of the invention.

[0094] Further, referring to Fig. 1, Fig. 2, Fig. 3 and Fig. 9, the frequency-dividing circuit 214 is configured to frequency-divide the 32768-Hz output signal outputted by oscillation of the quartz oscillator 210 and output a frequency-divided signal of one hour period to the corrected-pulse comparator circuit 216.

[0095] The corrected-pulse comparator circuit 216 is configured to compare between a detection signal of one hour period measured by the escape/speed-control device (see (1) of Fig. 8) and a frequency-divided signal of one hour period frequency-divided by the frequency-dividing circuit 214 (see (1) of Fig. 8), and counts a difference between them (see (3) of Fig. 8). This difference is a time to be corrected by correcting a time error in the mechanical timepiece of the invention.

[0096] The ultrasonic-motor drive circuit 468 is configured to output a drive signal to the ultrasonic motor 430 based on a signal corresponding to the difference outputted by the corrected-pulse comparator circuit 216.

[0097] Consequently, the corrected-pulse comparator circuit 216, the ultrasonic-motor drive circuit 468, the ultrasonic motor 430 and the regulator 420 constitute a watch-error adjusting section to control the operation of the balance with hairspring 140. The watch-error adjusting section is configured to control the operation of the train wheel 224 with a period of once per hour to once per day.

[0098] With this configuration, by driving the ultrasonic motor 430, the watch error of the mechanical timepiece can be adjusted in a manner corresponding to the difference shown in (3) of Fig. 8.

[0099] That is, referring to Fig. 3 and Fig. 9, if a contact of the pallet fork is detected by hitting the pallet-fork rod portion 142d on the pallet-fork detecting piezoelectric element 336, the waveform correcting circuit 332 inputs therein a detection signal outputted by the pallet-fork detecting piezoelectric element 336, and shapes a waveform thereof and outputs a corrected signal to the detection-signal frequency dividing circuit 334.

[0100] The waveform correcting circuit 332 inputs therein a detection signal counted by the pallet-fork detection signal count section and outputs a corrected signal shown in (5) of Fig. 10 to the detection-signal frequency dividing circuit 334. The detection-signal frequency dividing circuit 334 frequency-divides 10800 times the corrected signal outputted by the waveform correcting circuit 332 and outputs a corrected frequency-divided signal as shown in (1) of Fig. 8 to the corrected-pulse comparator circuit 216.

[0101] Next, the corrected-pulse comparator circuit 216 compares between a corrected frequency-divided signal outputted by the corrected-pulse comparator circuit 216 and a frequency-divided signal of with a period of one hour of the frequency-divided signal outputted by the frequency-dividing circuit 214, and counts a difference thereof.

[0102] Here, by inputting a signal of (5) of Fig. 10 to the corrected-pulse comparator circuit 216, the timing the pallet-fork rod portion 142d hits the pallet-fork detecting piezoelectric element 336 is known and accordingly the timing the pallet fork 142 stops is known. Accordingly, it is possible to detect a rotational direction that the balance with hairspring 140 is rotating from the timing the pallet fork 142 stops.

[0103] The detection-signal frequency dividing circuit 334 frequency-divides a corrected signal 10800 times and outputs a corrected frequency signal to the corrected-pulse comparator circuit 216.

[0104] The corrected-pulse comparator circuit 216 compares between a period of one hour measured by the escape/speed-control device and a period of one hour measured by the IC 212, and determines whether the watch error of the timepiece is fast or the watch error of the timepiece is slow.

[0105] Where the corrected-pulse comparing circuit 216 determines that the timepiece watch error is fast, the ultrasonic-motor drive circuit 468 causes the ultrasonic rotor 434 to rotate rightward (forward rotation, clockwise rotation) to rotate the regulator 420 leftward (reverse rotation, counterclockwise rotation) making slow the timepiece watch error.

[0106] Contrary to this, where the corrected-pulse comparing circuit 216 determines that the timepiece watch error is slow, the ultrasonic-motor drive circuit 468 causes the ultrasonic rotor 434 to rotate leftward (reverse rotation) to rotate the regulator 420 rightward (forward rotation) making fast the timepiece watch error.

[0107] The rotational direction and rotation angle value that the ultrasonic-motor drive circuit 468 rotates the ultrasonic rotor 434 based on a result of determination of the corrected-pulse comparator circuit 216 is previously determined by experiments in relationship between a watch error of the mechanical timepiece and a position of the regulator 420 and stored in the corrected-pulse comparator circuit 216.

[0108] In this configuration, the corrected-pulse comparator circuit 216, the ultrasonic-motor drive circuit 468, the ultrasonic motor 430 and the regulator 420 constitute a watch-error adjusting section for controlling the operation of the balance with hairspring 140 and adjusting the watch error of the mechanical timepiece. This watch-error adjusting section is configured to control the operation of the balance with hairspring 140 with a period of from once per hour to once per day.

[0109] As explained above, by using the invention, the watch error of the mechanical timepiece can be adjusted with accuracy.

(10) Second Embodiment of Mechanical Timepiece of the Invention

[0110] Next, explanation will be made on a second embodiment of a mechanical timepiece of the invention. In the below explanation, description is mainly on the points that the second embodiment of the mechanical timepiece is different from the first embodiment of the mechanical timepiece of the invention.

[0111] Referring to Fig. 12 and Fig. 13, a regulator 520 is rotatably mounted on the balance with hairspring 166. The rotation center of the regulator 520 is the same as a rotation center of the balance with hairspring 140. The regulator 520 includes a regulator body 522, a regulator gear 524, a stud bridge 526 and a stud rod 528. A bore provided in the rotation center of the regulator body 522 is rotatably fitted in the outer perophery of a balance upper bearing of the hairspring 140. The regulator gear 524 is a partly teethed gear (gear having teeth provided not in the entire periphery of an outer periphery but in part of the outer periphery as shown in Fig. 12) provided in an outer periphery of the regulator body 522.

[0112] The mainspring 140c in its portion near the outer periphery is supported between the stud bridge 526 and the stud rod 528. Consequently, by rotating the regulator 520 to position the stud bridge 526 and stud rod 528, an effective length of the mainspring 140c is determined. If the effective length of the stud mainspring 140c, a period of rotation of the balance with hairspring 140 is determined to determine a watch error of the mechanical timepiece.

[0113] A step motor 530 is mounted on the main plate 102. The step motor 530 has a stator 532, a rotor 534 and a coil block 536. A rotor pinion 534k is integrally formed with the rotor 534.

[0114] A rotor transmission wheel 540 is rotatably assembled on the main plate 102. The rotor transmission wheel 540 includes a rotor transmission gear 542 and a rotor transmission pinion 544. The rotor transmission gear 542 is in mesh with the rotor pinion 534k. The rotor transmission pinion 544 is in mesh with the regulator gear 524.

[0115] Consequently, by rotating the rotor 534, the rotor transmission wheel 540 rotates. By rotating the rotor transmission wheel 540, the regulator gear 424 rotates. In this structure, the rotor transmission wheel 540 constitutes a reduction train wheel.

[0116] The IC 572 includes a frequency dividing circuit 574 to inputs an output signal outputted due to vibration of the quartz oscillator 210 and frequency-divide the signal to output a signal concerning a time, a corrected-pulse comparator circuit 576 to compare a corrected pulse, a step-motor drive circuit 568 to output a drive signal for driving the step motor 530, a waveform correcting circuit 332 to correct a waveform of a detection signal and a detection-signal frequency dividing circuit 334 to frequency-divide a detection signal. A battery 220 constitutes a power supply to operate the IC 572. The quartz oscillator 210, the frequency-dividing circuit 574 in the IC 572 and the battery 220 constitute a time count section to count time.

[0117] Where the corrected-pulse comparator circuit 576 determines that the watch error of the timepiece is fast, the step motor drive circuit 568 causes the rotor 534 to rotate leftward (reverse rotation) to rotate the regulator 420 leftward (reverse rotation) making slow the watch error of the timepiece.

[0118] Contrary to this, where the corrected-pulse comparator circuit 576 determines that the watch error of the timepiece is slow, the step motor drive circuit 568 causes the rotor 534 to rotate rightward (forward rotation) to rotate the regulator 420 rightward (forward rotation) making fast the watch error of the timepiece.

[0119] The value of rotation direction and rotation angle that the step-motor drive circuit 568 rotates the rotor 534 based on a result of determination of the corrected-pulse comparator circuit 576 is previously determined by experiments in relationship between a watch error of the mechanical timepiece and a position of the regulator 520 and stored in the corrected-pulse comparator circuit 576.

[0120] With this structure, the corrected-pulse comparator circuit 576, the step-motor drive circuit 568, the step motor 530, the rotor transmission wheel 540 and regulator 520 constitute a watch-error adjusting section 550 to control the operation of the balance with hairspring 140 and adjust a watch error of the mechanical timepiece. This watch-error adjusting section 550 is configured to control the operation of the balance with hairspring 140 with a period of from once per hour to once per day.

[0121] By this configuration, it is possible to adjust a watch error of the mechanical timepiece by a simple adjusting process. In the second embodiment of the mechanical timepiece of the invention, the configuration of the step-motor drive circuit 568 is simpler than the configuration of the above-stated ultrasonic-motor drive circuit 468 and the structure of the step motor 530 is simpler than the structure of the above-stated ultrasonic motor 430.

[0122] The other features of the second embodiment of the mechanical timepiece of the invention are the same as those of the first embodiment of the mechanical timepiece of the invention. Accordingly, the other features of the second embodiment of the mechanical timepiece of the invention are herein applied by the description of the first embodiment of the mechanical timepiece of the invention, avoiding duplicated description.

(11) Circuit Configuration of Mechanical Timepiece of the Invention

[0123] Furthermore, in any of the embodiment of the mechanical timepiece of the invention, the circuits performing various functions may be configured in the IC and the IC may be a PLA-IC incorporating a program to carry out various operations. Also, in any of the embodiments of the mechanical timepiece of the invention, it is possible to use, as required, external elements, such as resistors, capacitors, coils, diodes and transistors together with the IC.

[INDUSTRIAL APPLICABILITY]

[0124] The mechanical timepiece of the present invention is suitable for manufacturing a high-accuracy mechanical timepiece.

[0125] In the mechanical timepiece, by rotating the regulator by the rotation of the rotor, the vibration period of the balance with hairspring is varied making possible to accurately adjust the watch error.

Claims

1. In a mechanical timepiece having a movement structured having a mainspring constituting a power source for the mechanical timepiece, a train wheel rotating due to a rotation force of the mainspring upon being rewound, an escape/speed-control device for controlling rotation of the train wheel, the escape/speed-control device including a balance with hairspring alternately repeating right and left rotation, an escape wheel and pinion rotating based on rotation of the train wheel and a pallet fork controlling rotation of the escape wheel and pinion based on operation of the balance with hairspring, the balance with hairspring including a stud mainspring, a stud stem and a stud wheel, the mechanical timepiece **characterized by** comprising:

   a time count section to count time having a quartz oscillator (210) constituting source oscillation, an IC (212) including a frequency-dividing section (214) to input an output signal outputted due to oscillation of said quartz oscillator (210) and output a signal concerning a time by frequency-dividing the signal, and a power source (220) to operate said IC (212);
   a watch error section (330) for detecting a watch error of said mechanical timepiece; and
   a watch-error adjusting section (470, 550) including a regulator (420) operating based on a count signal counted by said time count section and an operation state signal representative of a watch error detected by said watch-error detecting section (330).

2. A mechanical timepiece as claimed in claim 1, **characterized in that** said watch-error adjusting section (470, 550) is configured to operate said regulator with a period of from once per hour to once per day.

3. A mechanical timepiece as claimed in claim 1 or claim 2, **characterized in that** said watch-error detecting section (330) includes a pallet-fork detecting piezoelectric element (336) provided on a bank pin (102d) to detect operation of said pallet fork (142), and a pallet-fork signal count section to count pallet-fork detection signals outputted by said pallet-fork detecting piezoelectric element (336).

4. A mechanical timepiece as claimed in any one of claim 1 to claim 4, **characterized in that** said watch-error adjusting section (470) includes a regulator (420) rotating due to rotation of a motor.

5. A mechanical timepiece as claimed in claim 4, **characterized in that** said motor is an ultrasonic motor (430).

6. A mechanical timepiece as claimed in claim 4, **characterized in that** said motor is a step motor (530).

FIG. 1

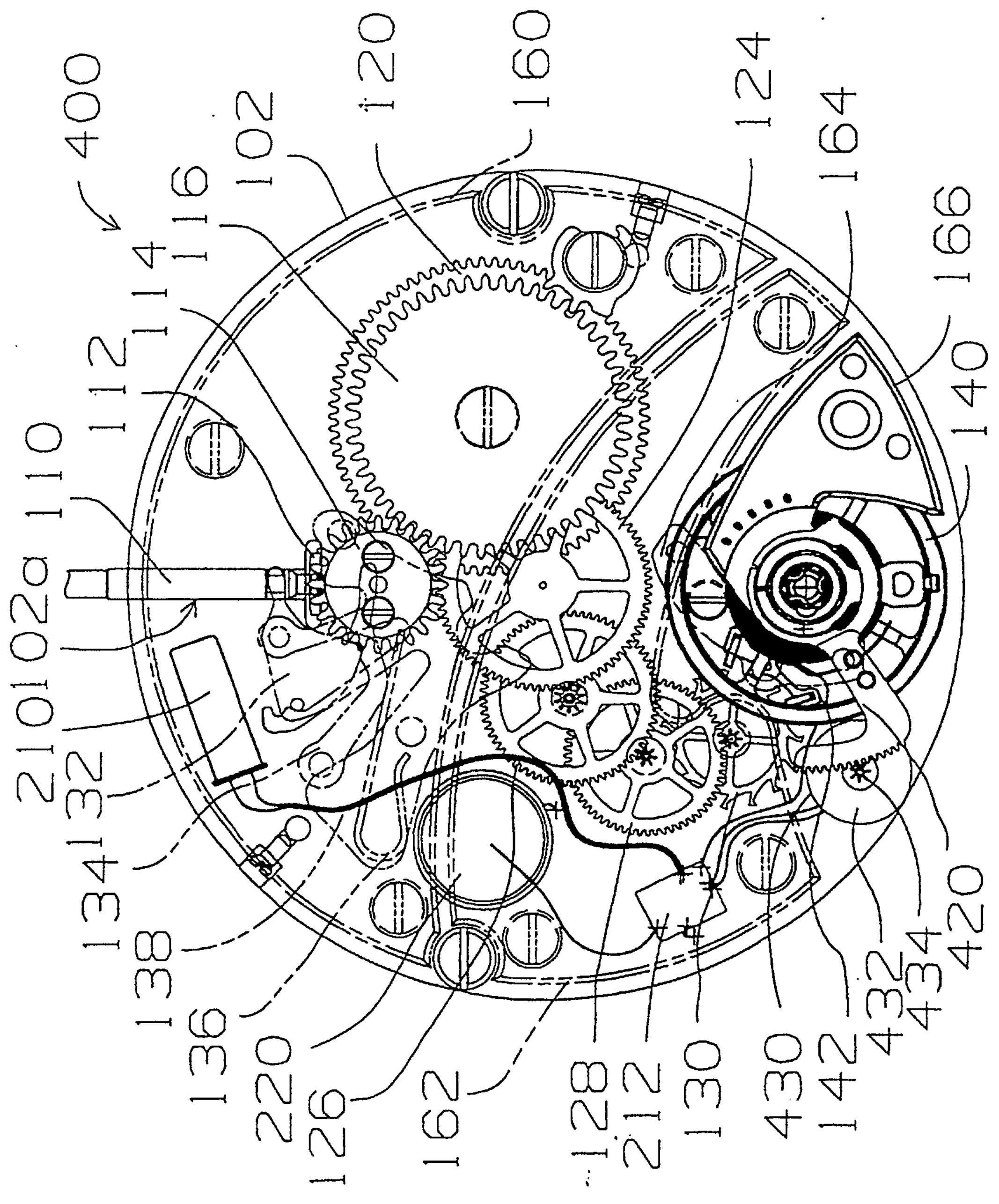

400
102
120
160
124
164
166
140
116
114
112
110
102a
210
132
134
138
136
220
126
162
128
212
130
430
142
432
434
420

FIG. 2

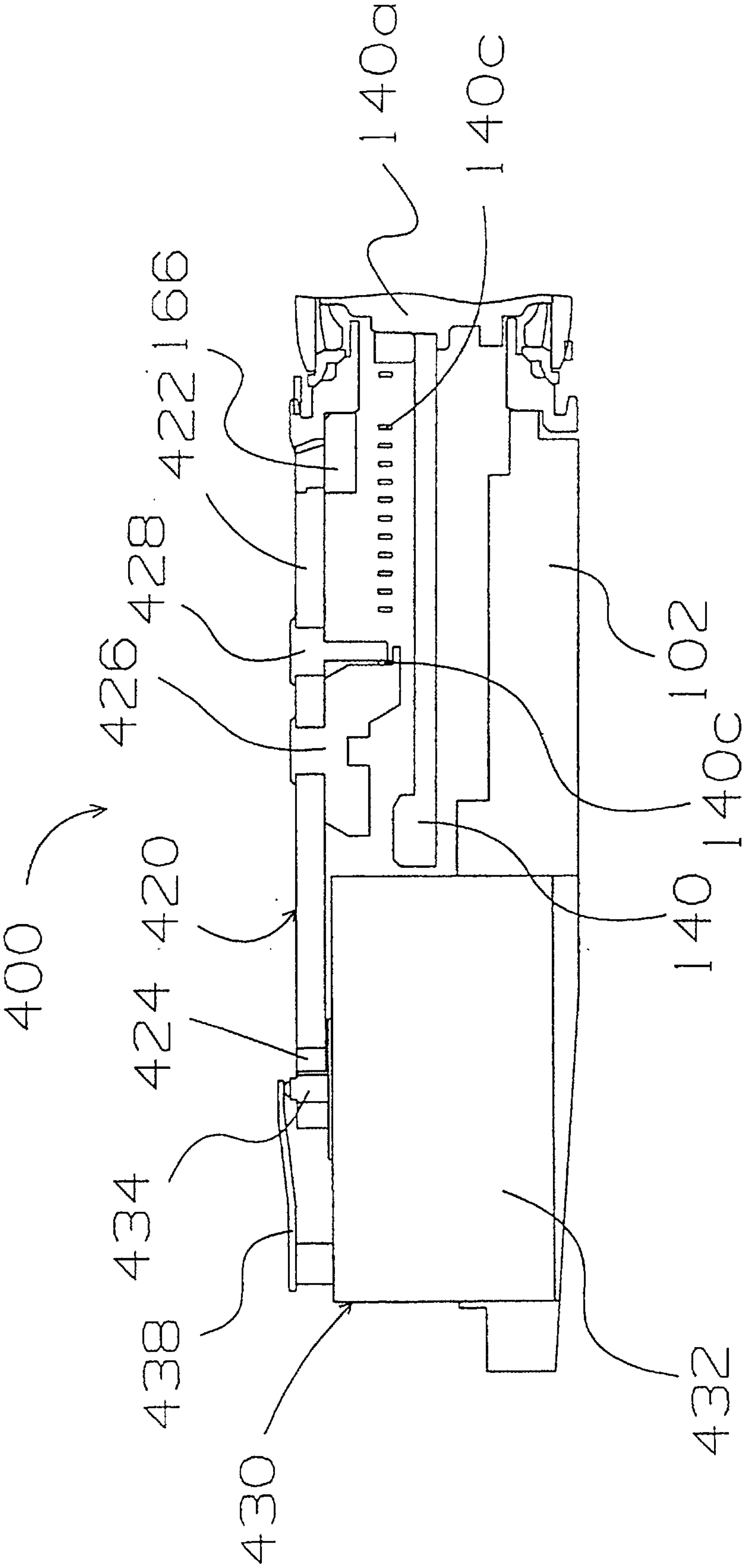

400
420
424
434
438
430
426
428
422
166
140a
140c
102
140c
140
432

FIG.3

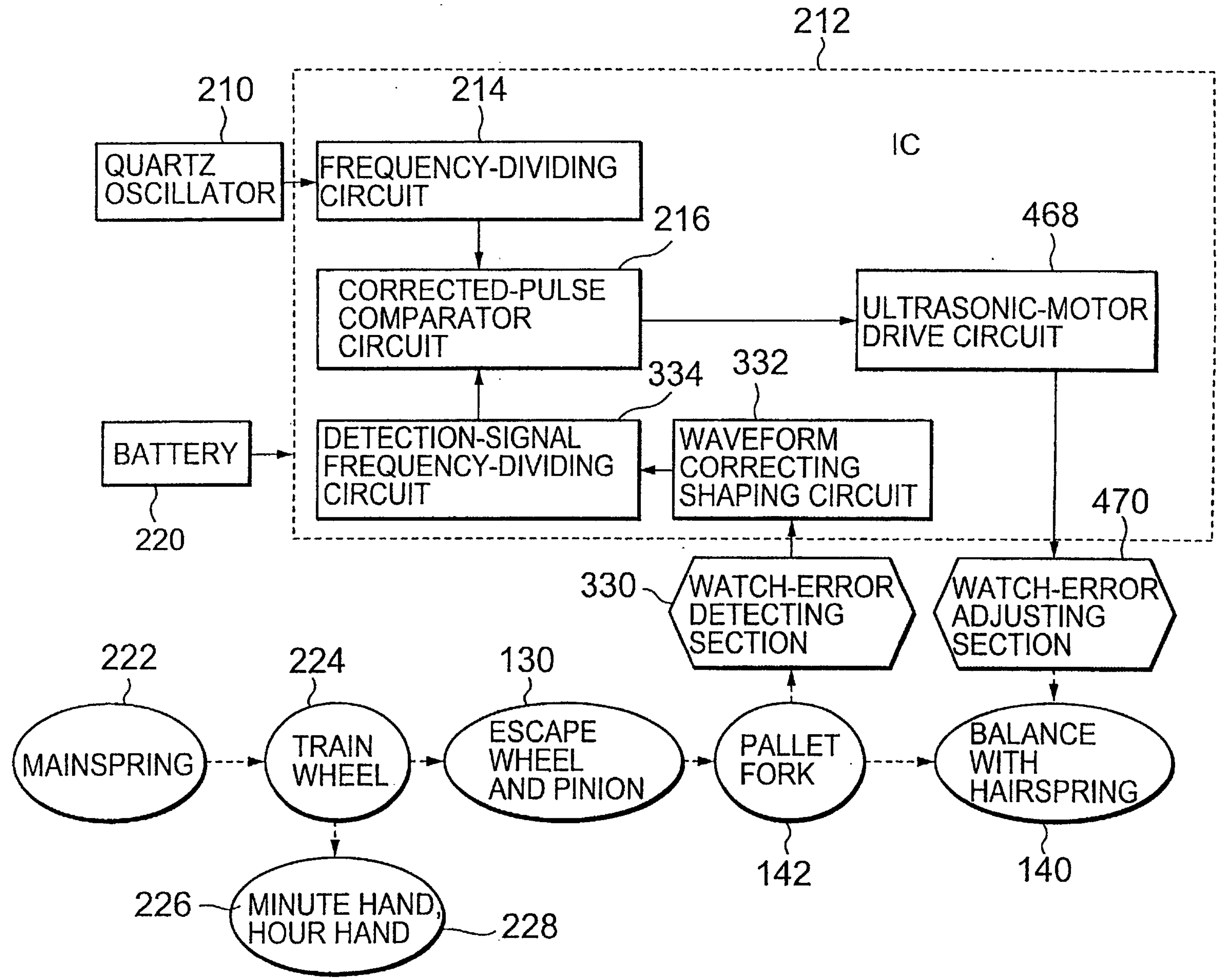

212
IC
210
QUARTZ OSCILLATOR
214
FREQUENCY-DIVIDING CIRCUIT
216
CORRECTED-PULSE COMPARATOR CIRCUIT
468
ULTRASONIC-MOTOR DRIVE CIRCUIT
334
332
BATTERY
220
DETECTION-SIGNAL FREQUENCY-DIVIDING CIRCUIT
WAVEFORM CORRECTING SHAPING CIRCUIT
470
330
WATCH-ERROR DETECTING SECTION
WATCH-ERROR ADJUSTING SECTION
222
224
130
MAINSPRING
TRAIN WHEEL
ESCAPE WHEEL AND PINION
PALLET FORK
BALANCE WITH HAIRSPRING
142
140
226
MINUTE HAND, HOUR HAND
228

FIG. 4

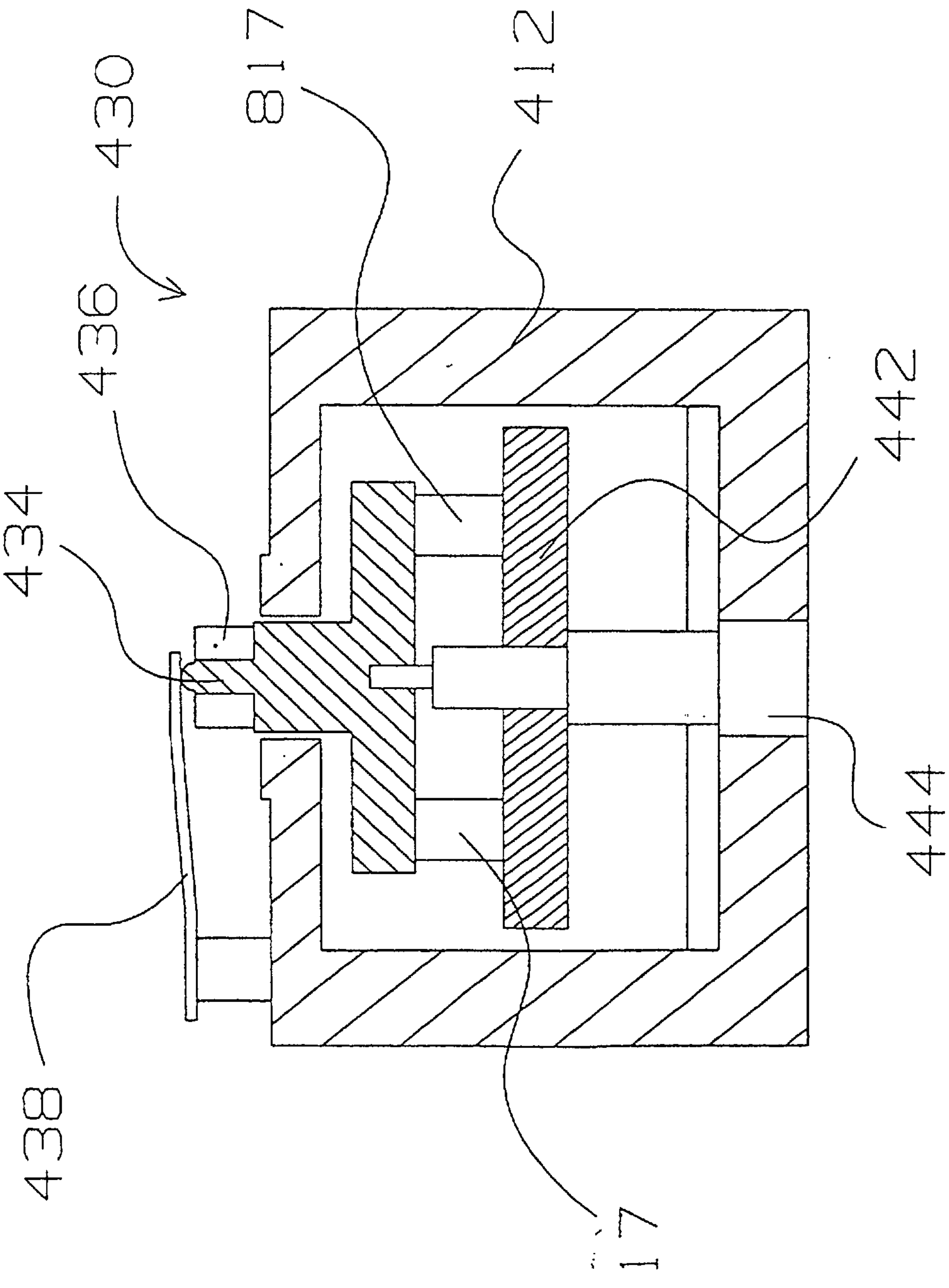


FIG.5

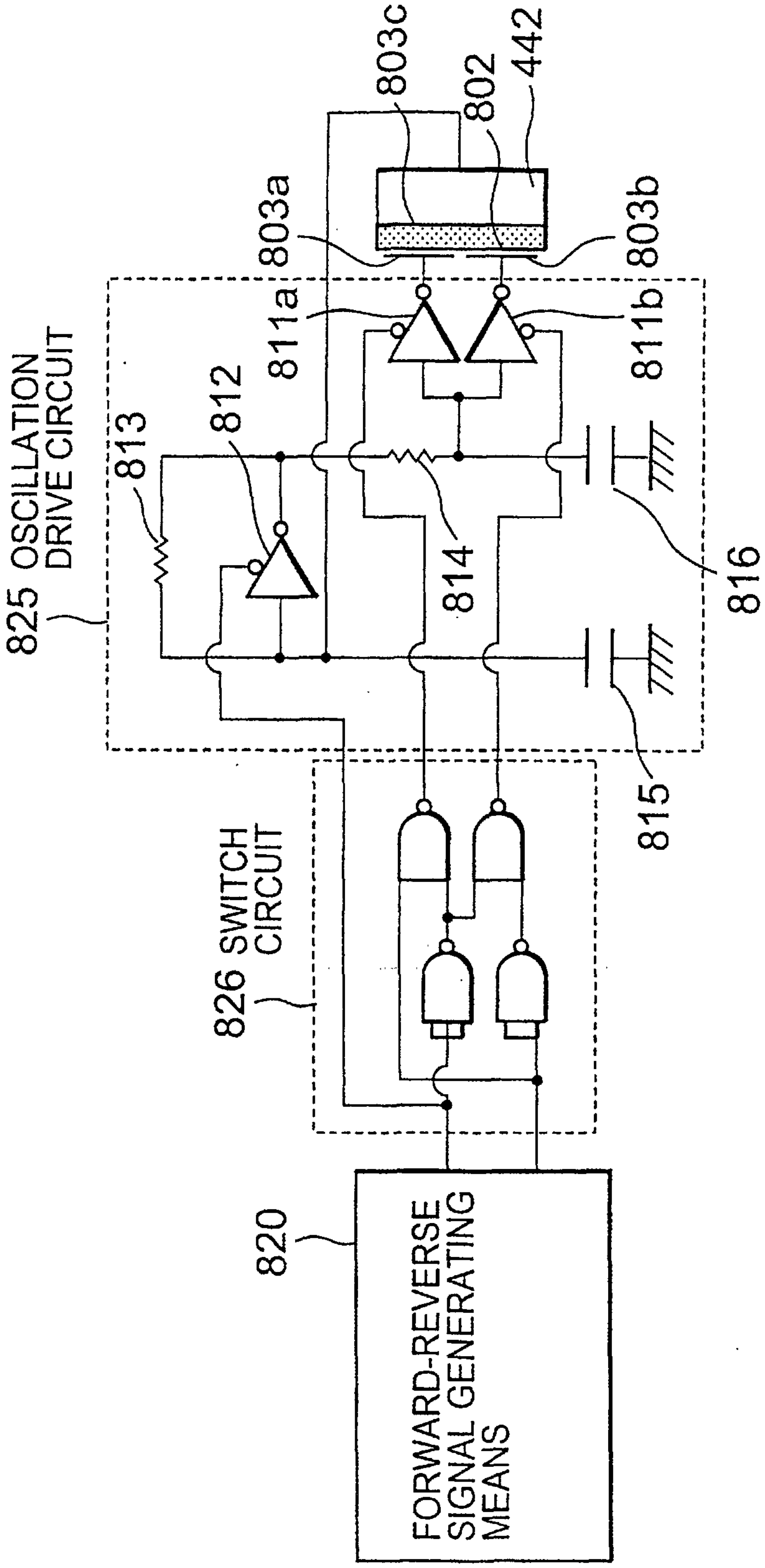

825 OSCILLATION DRIVE CIRCUIT
826 SWITCH CIRCUIT
820
FORWARD-REVERSE SIGNAL GENERATING MEANS
803c
802
442
803a
803b
811a
811b
812
813
814
815
816

FIG.6

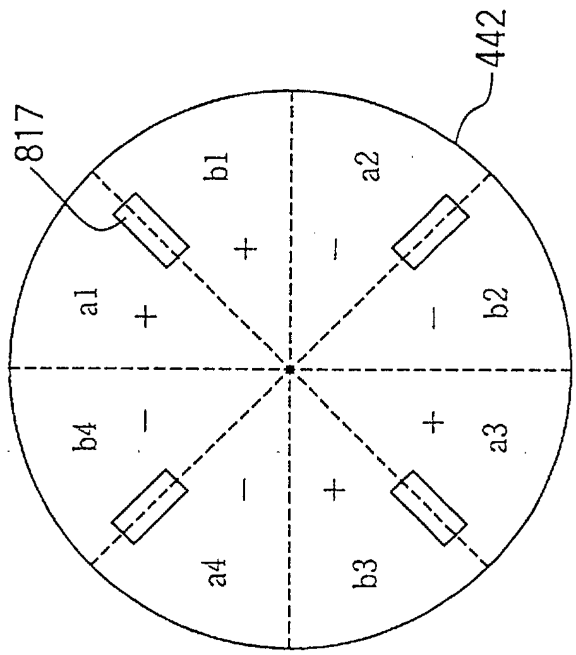
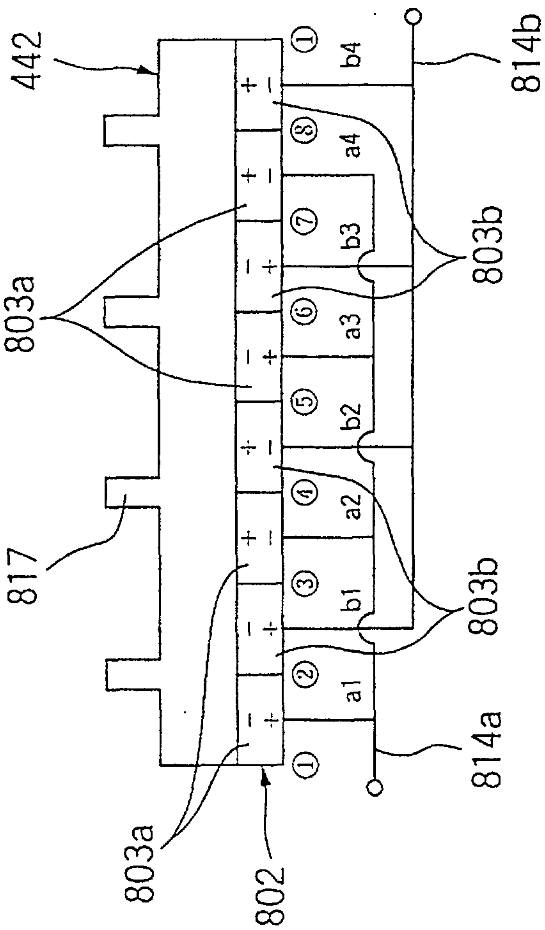


FIG. 7



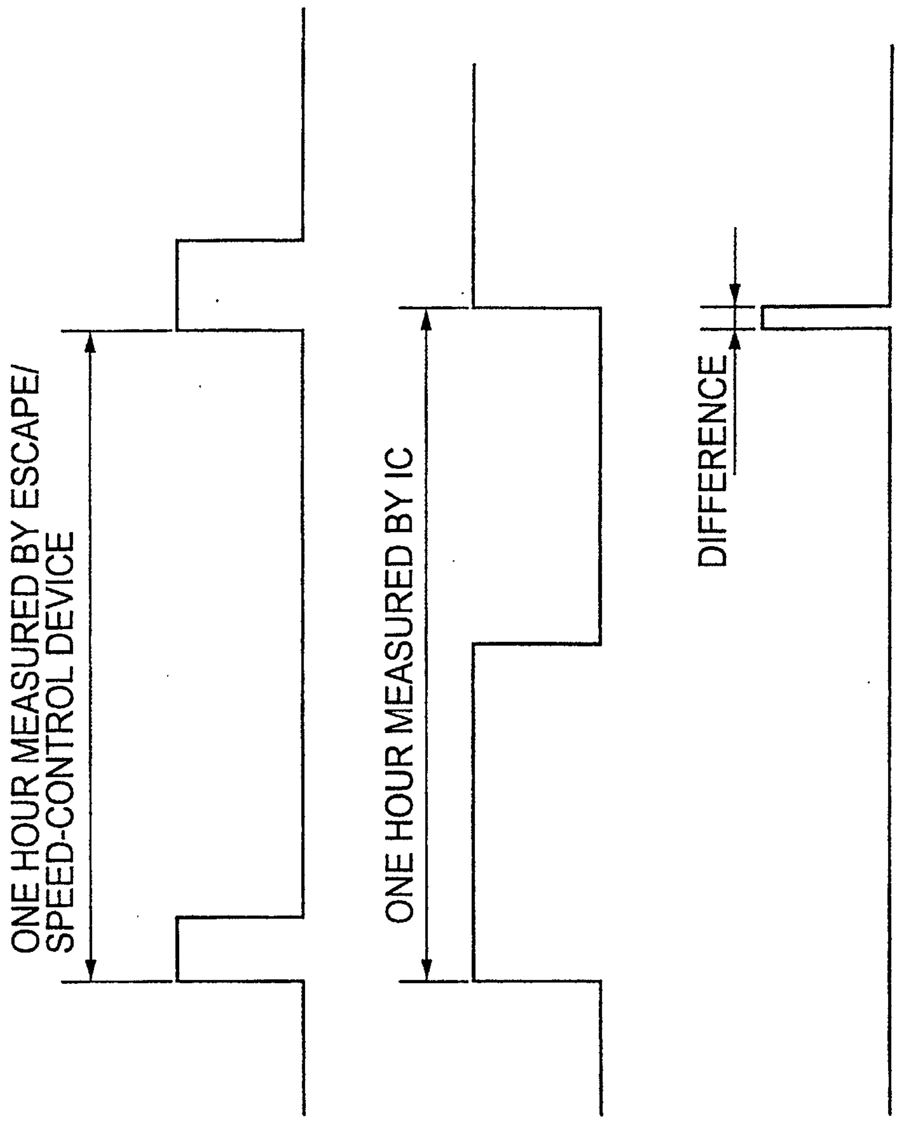
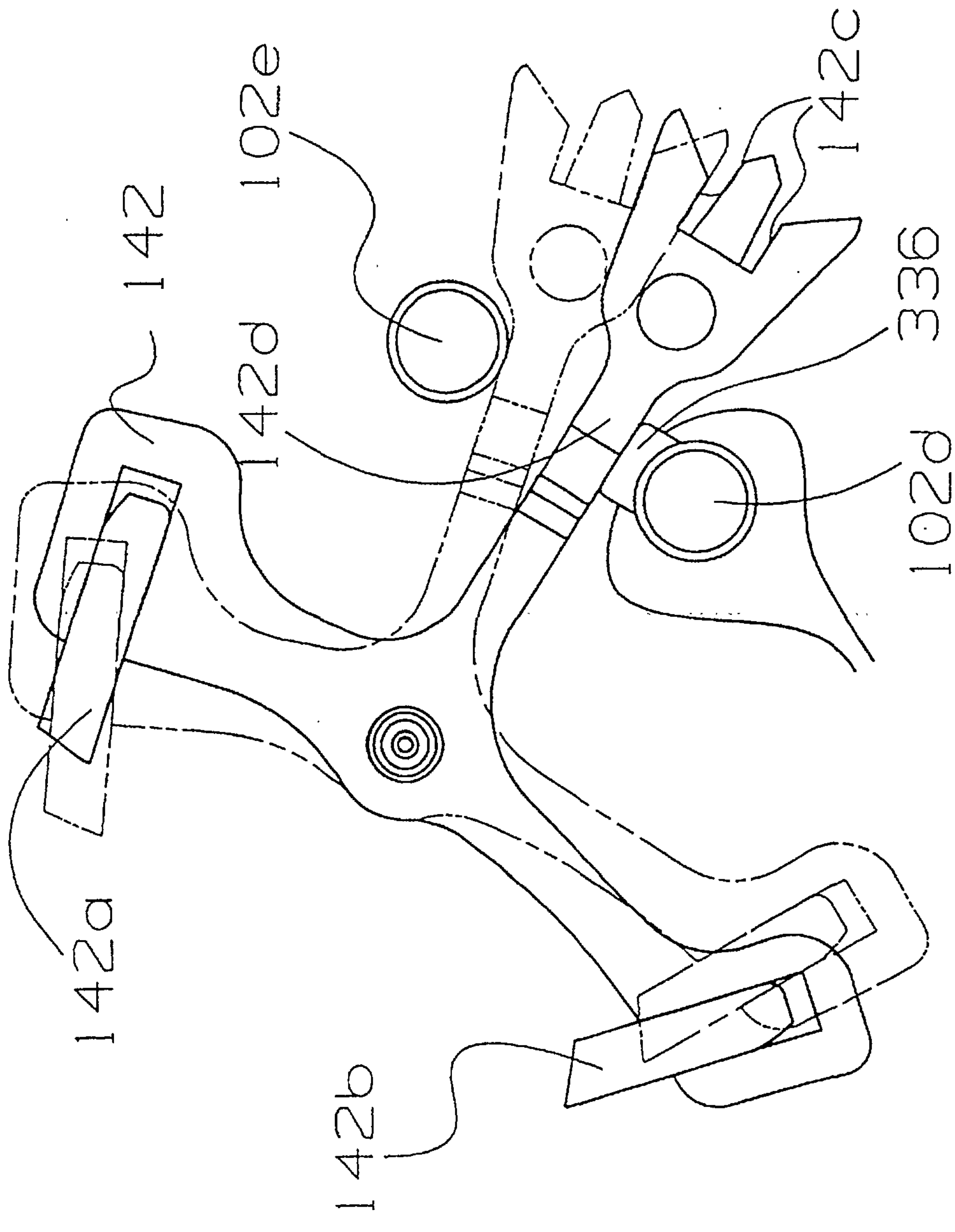


FIG.8(1)

FIG.8(2)

FIG.8(3)

FIG. 9



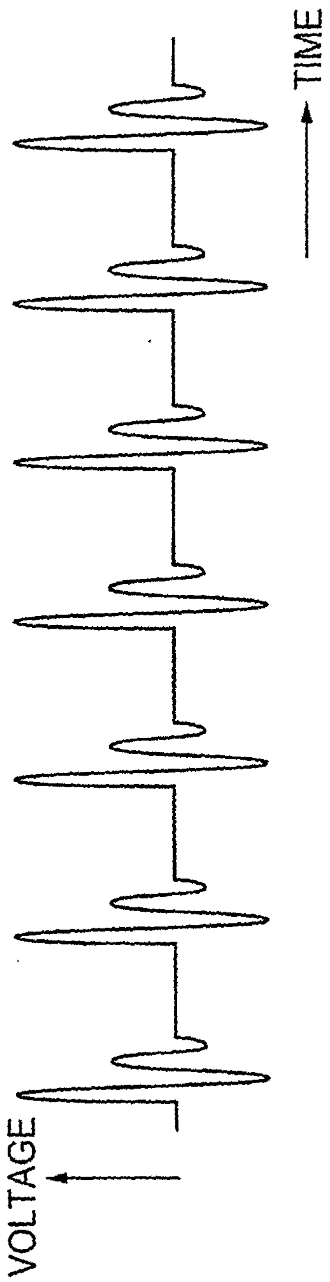


FIG.10(4)

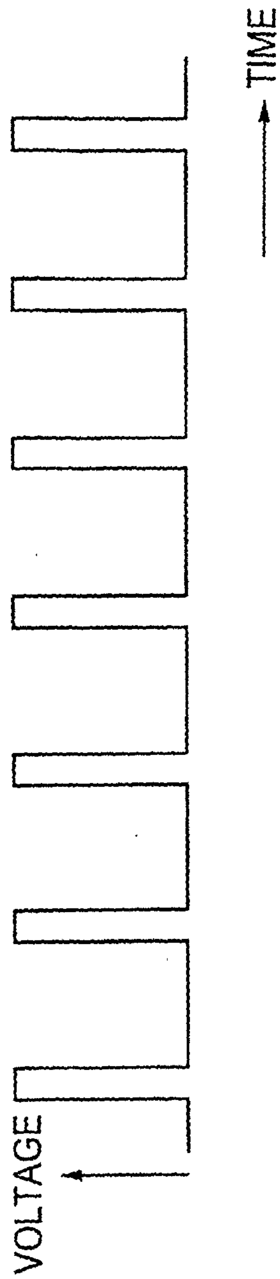


FIG.10(5)

FIG.11

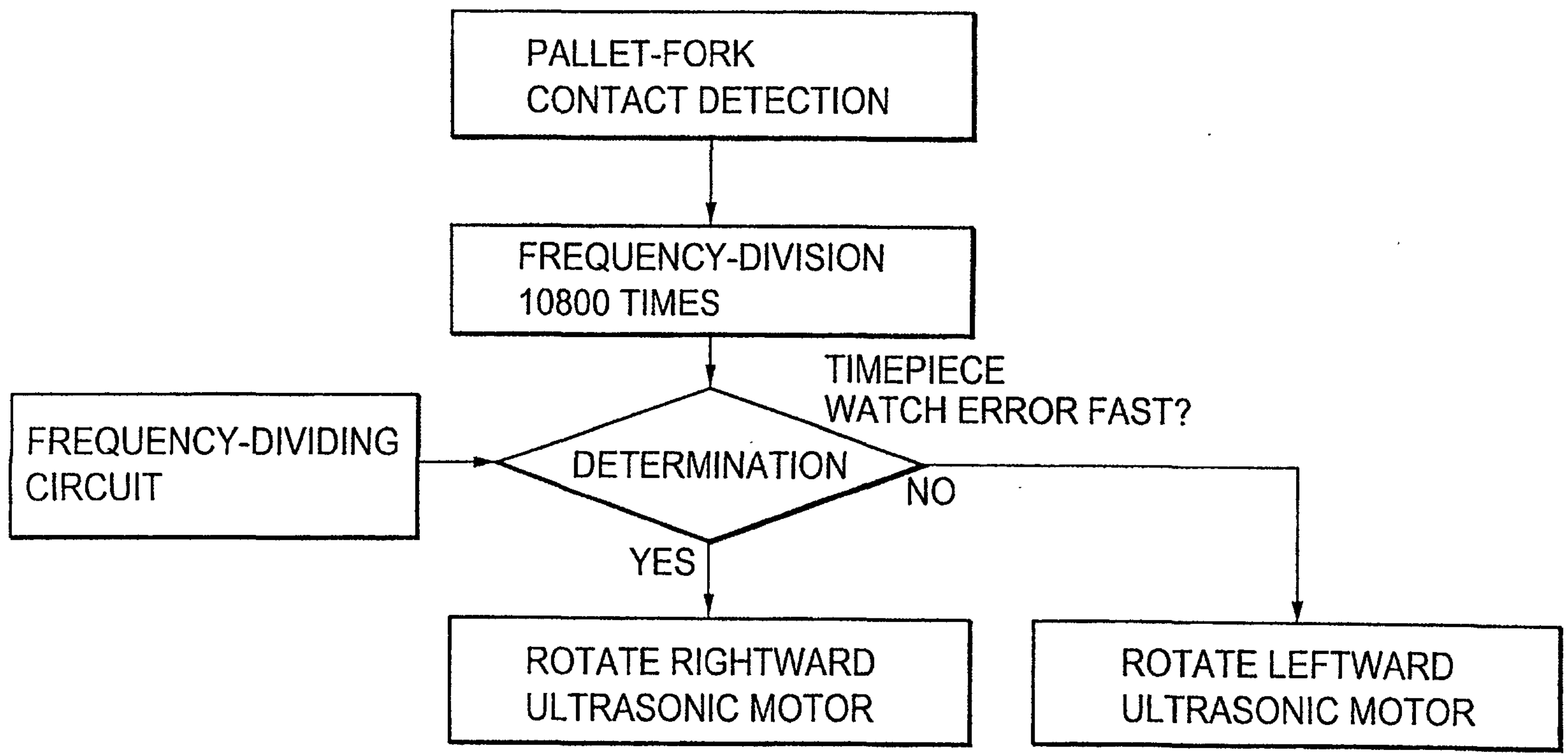

PALLET-FORK
CONTACT DETECTION
FREQUENCY-DIVISION
10800 TIMES
TIMEPIECE
WATCH ERROR FAST?
FREQUENCY-DIVIDING
CIRCUIT
DETERMINATION
NO
YES
ROTATE RIGHTWARD
ULTRASONIC MOTOR
ROTATE LEFTWARD
ULTRASONIC MOTOR

FIG. 12

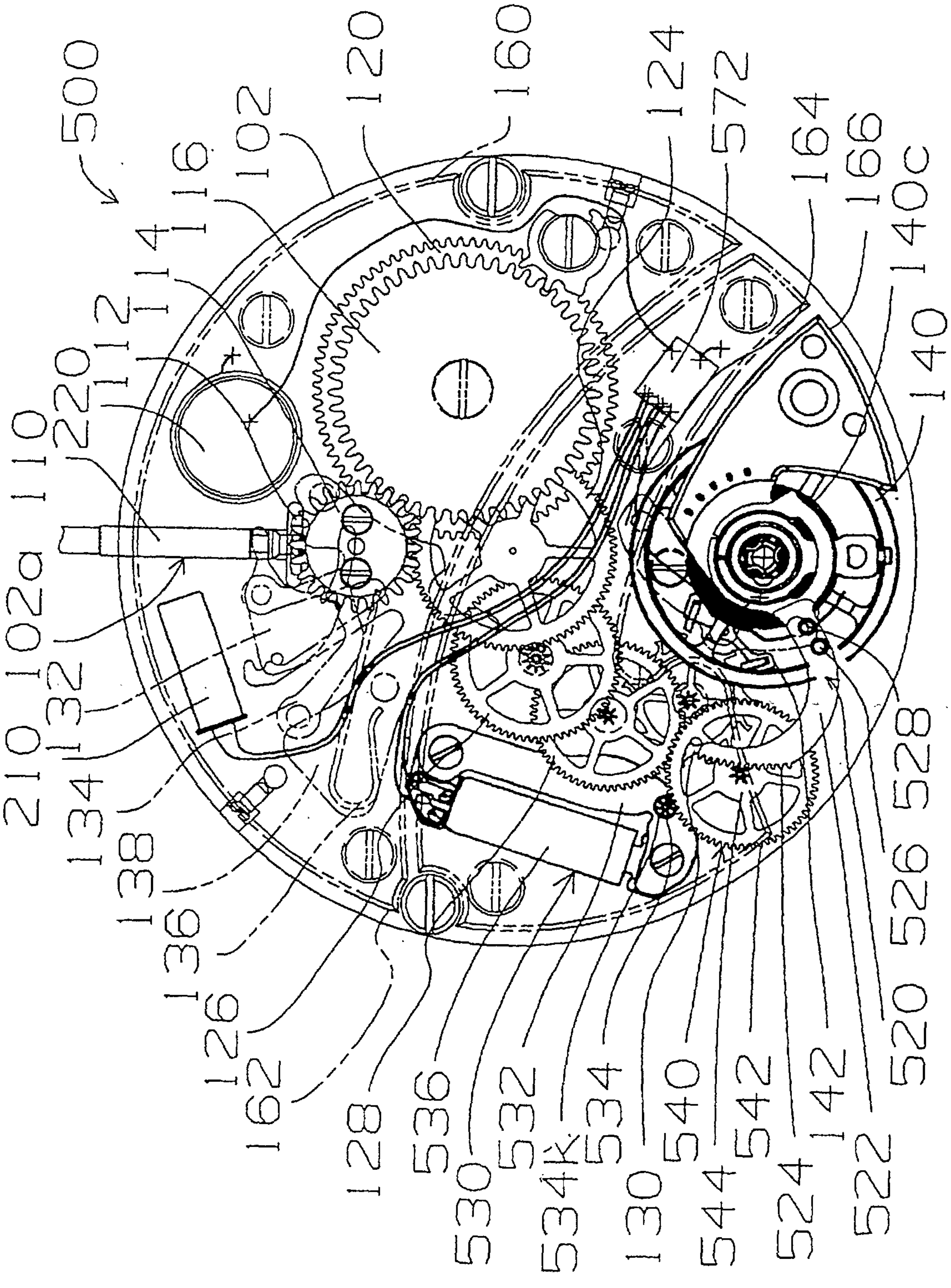

500
102
160
120
116
114
112
220
110
102a
132
210
134
138
136
126
162
128
536
530
532
534K
534
130
540
544
542
524
142
522
520
526
528
124
572
164
166
140c
140

FIG.13

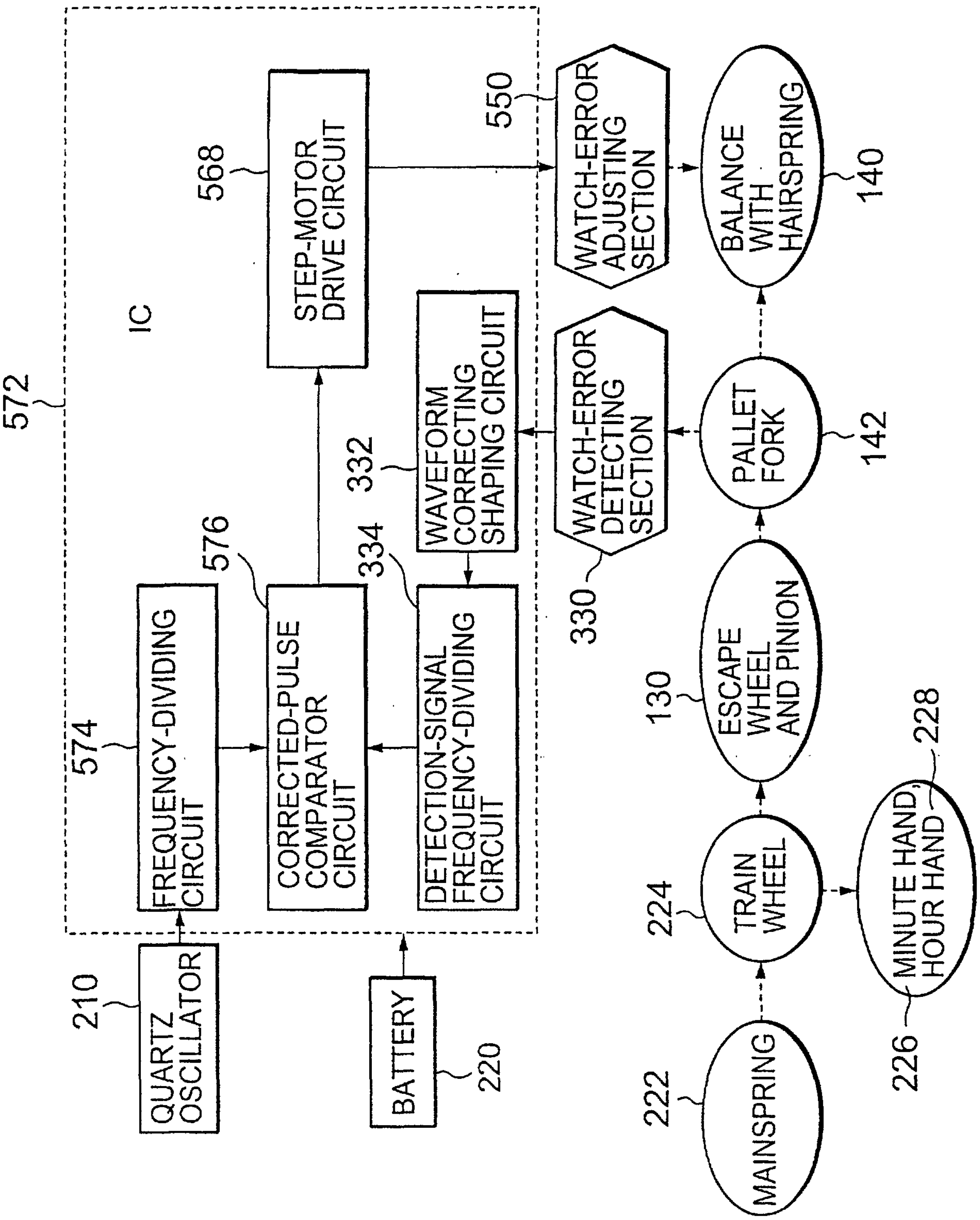

572
IC
210
QUARTZ OSCILLATOR
220
BATTERY
574
FREQUENCY-DIVIDING CIRCUIT
576
CORRECTED-PULSE COMPARATOR CIRCUIT
334
DETECTION-SIGNAL FREQUENCY-DIVIDING CIRCUIT
332
WAVEFORM CORRECTING SHAPING CIRCUIT
568
STEP-MOTOR DRIVE CIRCUIT
330
WATCH-ERROR DETECTING SECTION
550
WATCH-ERROR ADJUSTING SECTION
222
MAINSPRING
224
TRAIN WHEEL
226
228
MINUTE HAND, HOUR HAND
130
ESCAPE WHEEL AND PINION
142
PALLET FORK
140
BALANCE WITH HAIRSPRING

FIG. 14

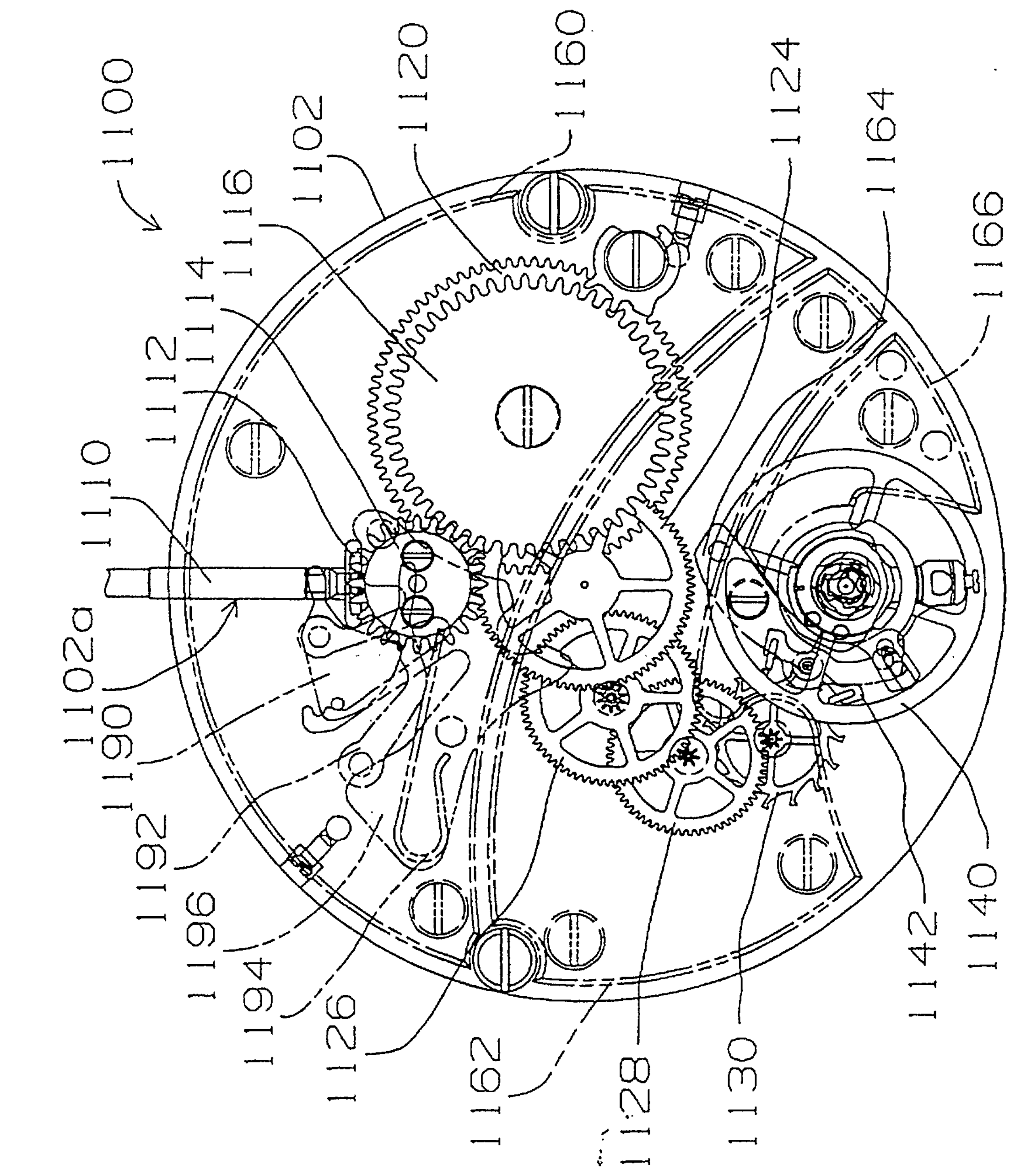

1100
1102
1120
1160
1124
1164
1166
1116
1114
1112
1110
1102a
1190
1192
1196
1194
1126
1162
1128
1130
1142
1140

FIG. 15

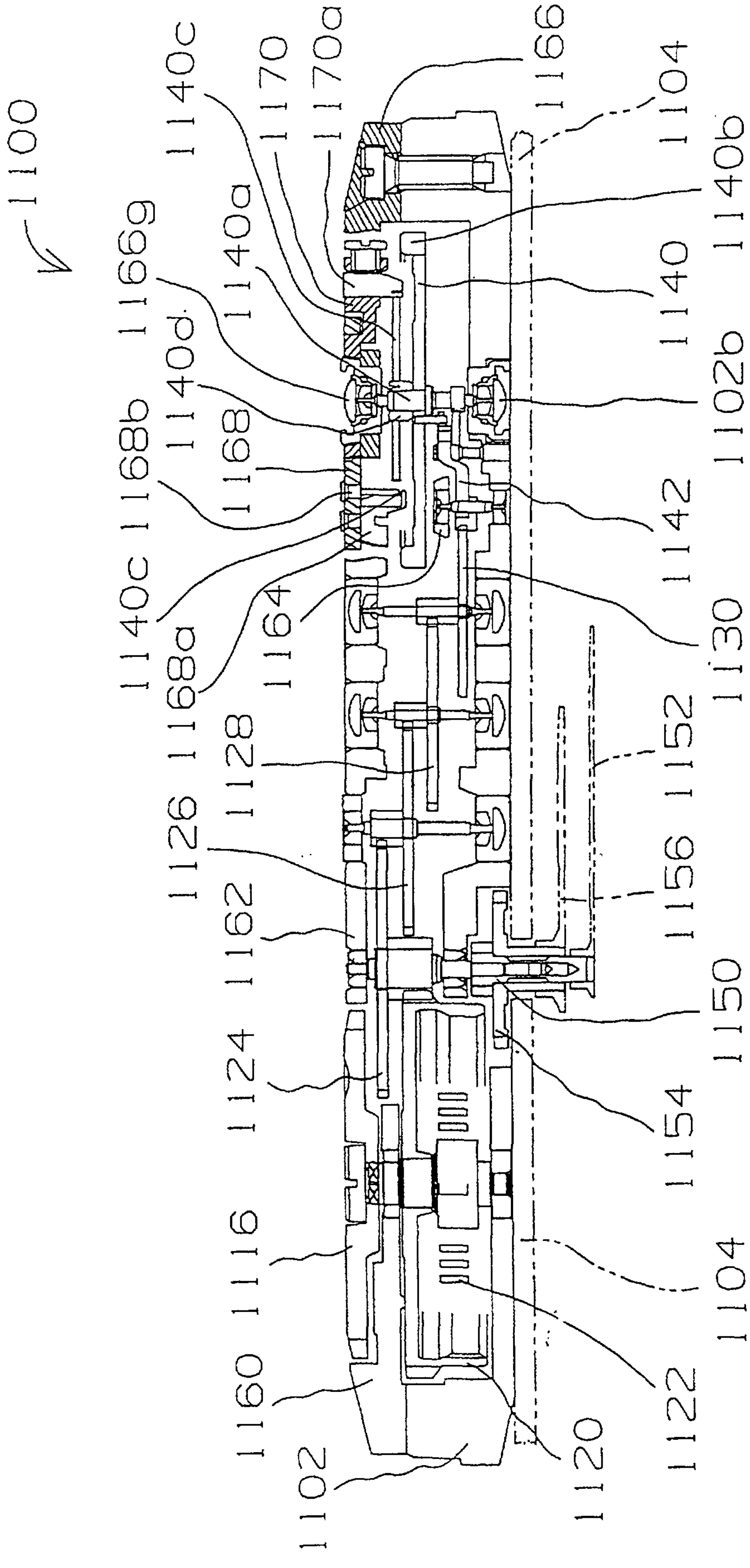

1100
1166g
1140a
1140c
1170
1170a
1166
1104
1140b
1140
1102b
1140d
1168
1168b
1140c
1168a
1164
1142
1130
1128
1126
1152
1156
1162
1150
1124
1154
1116
1104
1160
1122
1120
1102

FIG.16

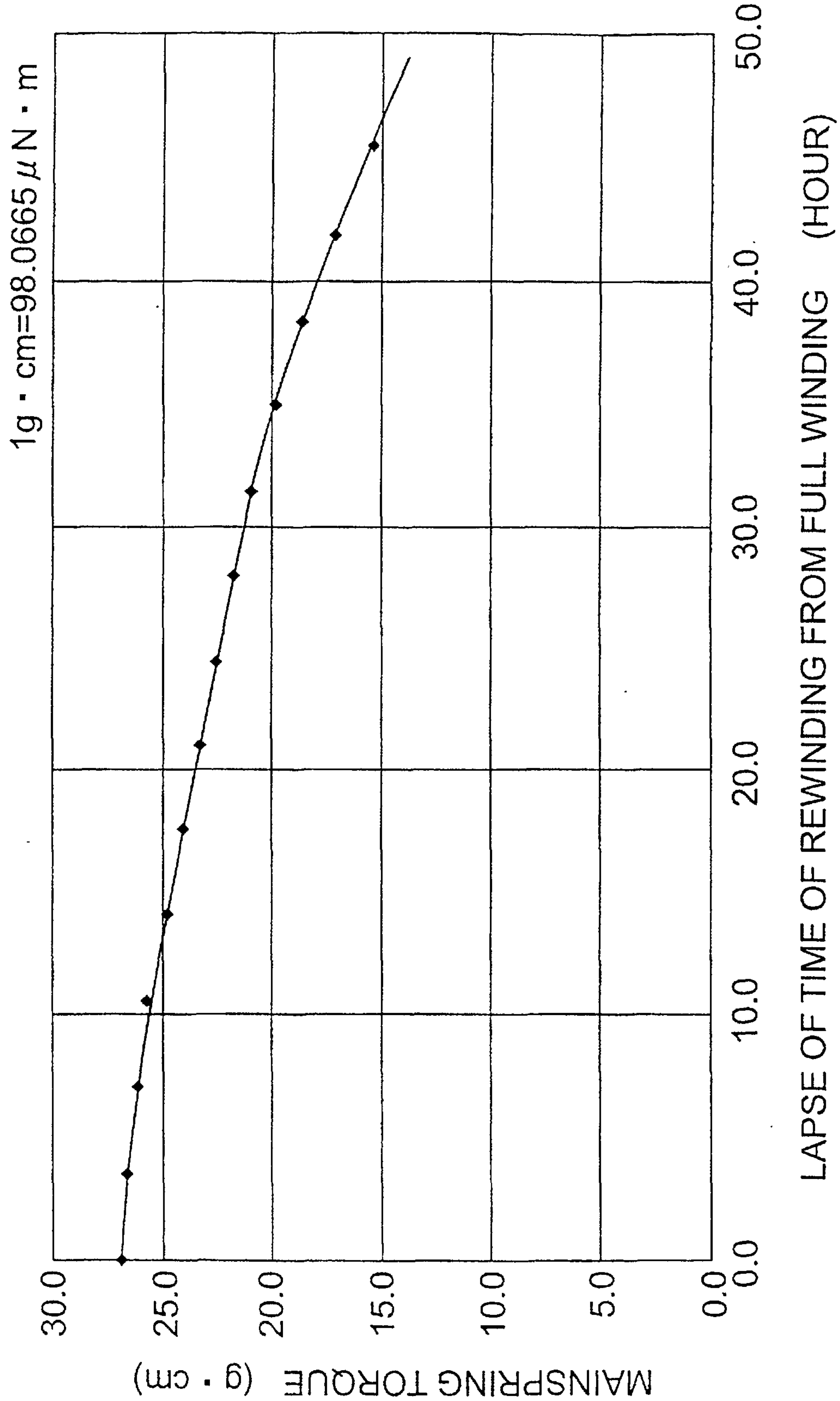

1g · cm=98.0665 μ N · m
MAINSPRING TORQUE (g · cm)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
0.0
10.0
20.0
30.0
40.0
50.0
LAPSE OF TIME OF REWINDING FROM FULL WINDING (HOUR)

FIG.17

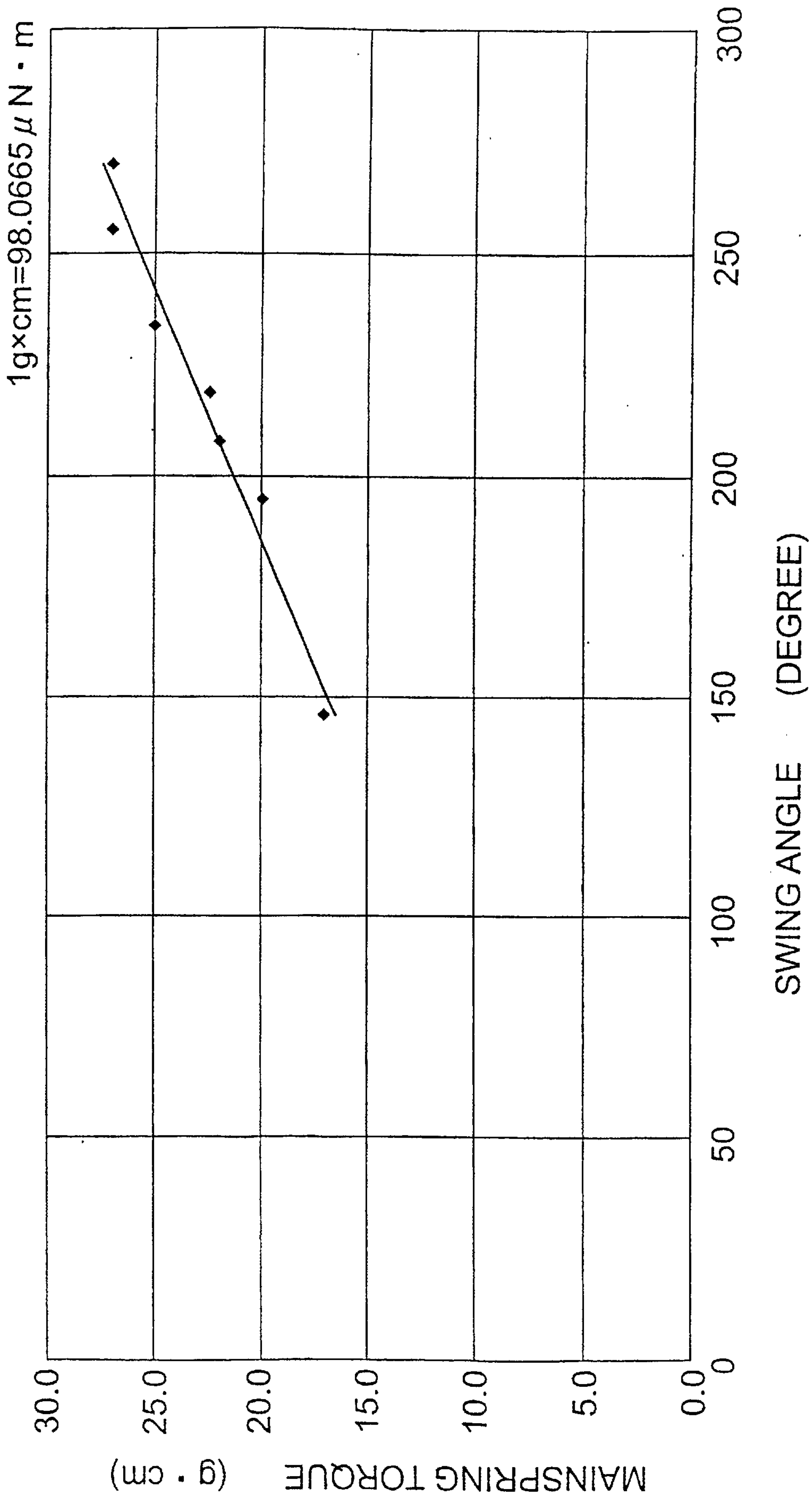

1g×cm=98.0665 μN · m
MAINSPRING TORQUE (g · cm)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
SWING ANGLE (DEGREE)
0
50
100
150
200
250
300

FIG.18

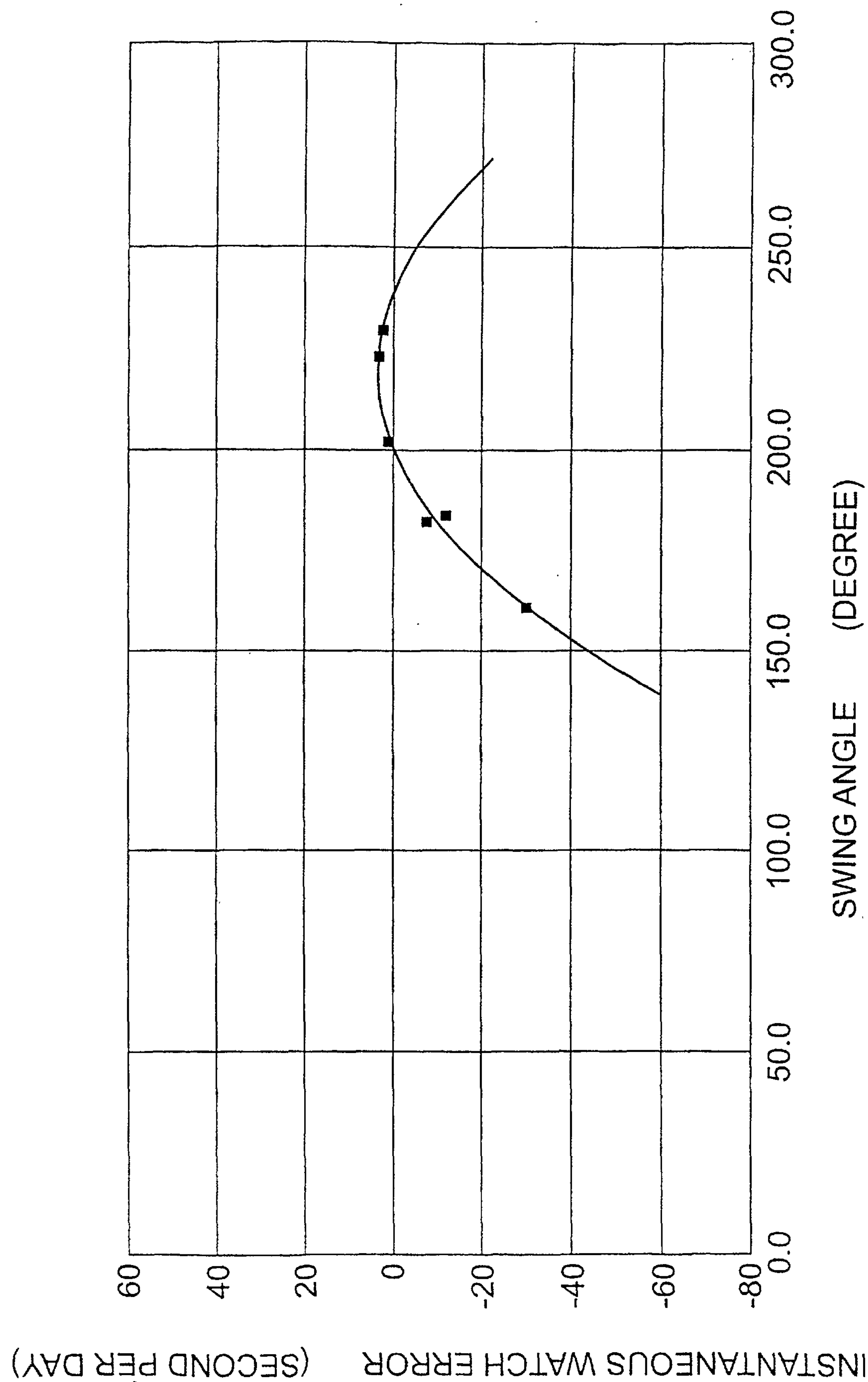
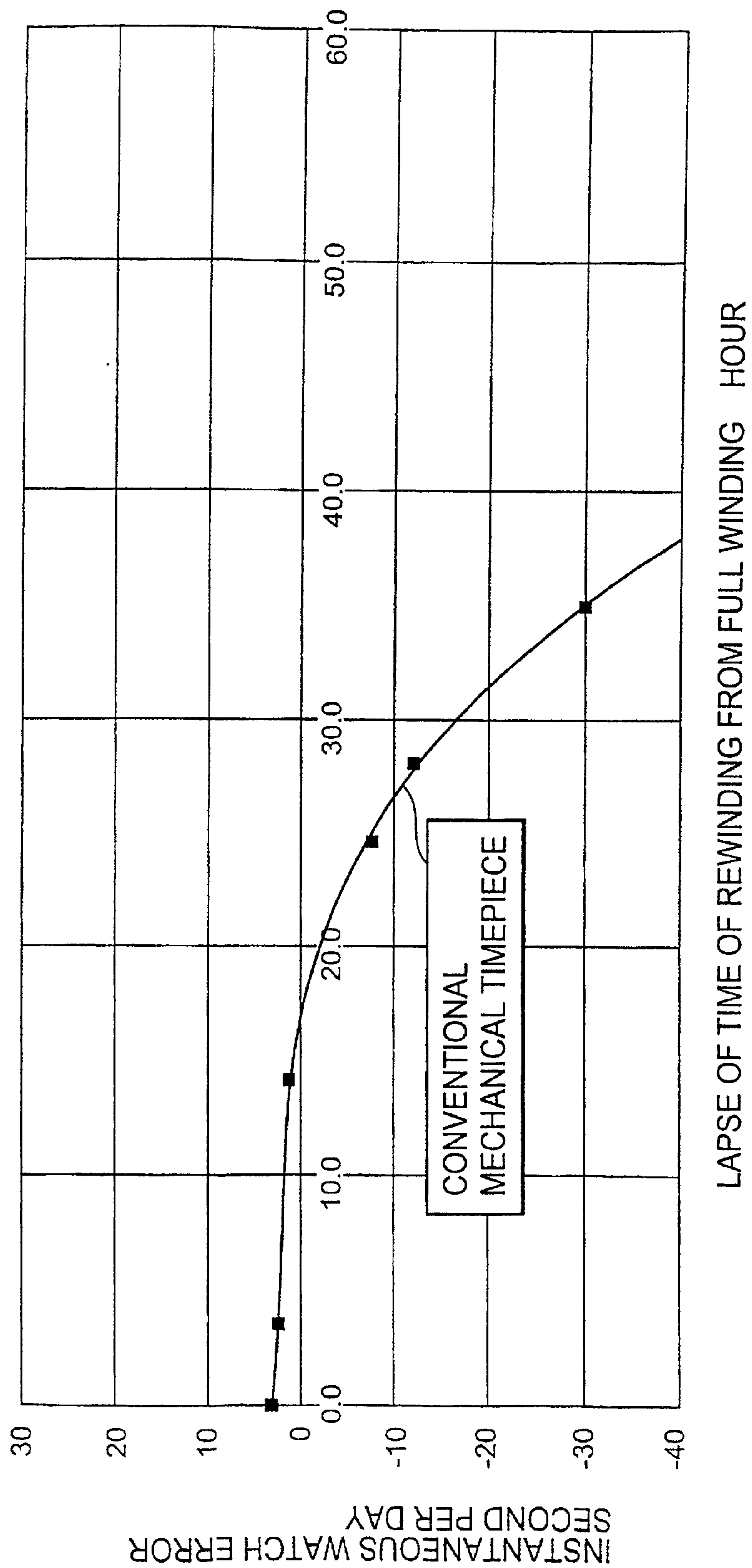

INSTANTANEOUS WATCH ERROR (SECOND PER DAY)
60
40
20
0
-20
-40
-60
-80
0.0
50.0
100.0
150.0
200.0
250.0
300.0
SWING ANGLE (DEGREE)

FIG.19


CONVENTIONAL
MECHANICAL TIMEPIECE
0.0
10.0
20.0
30.0
40.0
50.0
60.0
LAPSE OF TIME OF REWINDING FROM FULL WINDING HOUR
30
20
10
0
-10
-20
-30
-40
INSTANTANEOUS WATCH ERROR
SECOND PER DAY

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/00677

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl^7 G04B17/20, 18/02, G04C3/04

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^7 G04B17/00-18/00, G04C3/04-3/06, G04C9/00

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

Jitsuyo Shinan Koho	1992-1996	Toroku Jitsuyo Shinan Koho	1994-2000
Kokai Jitsuyo Shinan Koho	1971-2000	Jitsuyo Shinan Toroku Koho	1996-2000

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB, 1378826, A (DIXI S.A.), 27 December, 1974 (27.12.74), Full text; Figs. 1 to 4 & CH, 1801671, A & JP, 48-66466, A & DE, 2258963, A1 & FR, 2162404, A	1-6
A	JP, 4-319691, A (KANSEI CORPORATION), 19 November, 1992 (19.11.92), Full text; all drawings (Family: none)	1-6
A	US, 4196579, A (Urgor Uhrenfabrik Schwenningen, Haller, Jauch und Pabst GmbH & Co.), 08 April, 1980 (08.04.80), Full text; all drawings & DE, 2749006, A1 & JP, 54-74781, A & FR, 2408167, A & GB, 2010540, A & CH, 632635, A & IT, 1099898, A	1-6
A	US, 5268881, A (Eric Damm, Harry Wolff), 07 December, 1993 (07.12.93), Full text; all drawings	1-6

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 10 March, 2000 (10.03.00)	Date of mailing of the international search report 21 March, 2000 (21.03.00)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP00/00677

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	& DE, 4108935, A1 & JP, 5-203765, A & EP, 504625, A1	
A	JP, 30-3290, Y1 (Masaaki TAKAHASHI), 19 March, 1955 (19.03.55), Full text; all drawings (Family: none)	1-6
A	JP, 46-26268, B1 (Seiko Instr. & Electronics Ltd.), 29 July, 1971 (29.07.71), Full text; all drawings (Family: none)	3

Form PCT/ISA/210 (continuation of second sheet) (July 1992)