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Haydon

[11] **3,732,685**

[45] **May 15, 1973**

[54] CLOCK MECHANISM

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[73] Assignee: **Tri-Tech, Inc.,** Westbury, Conn.

[22] Filed: **Apr. 3, 1972**

[21] Appl. No.: **240,623**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 45,609, June 12, 1970, Pat. No. 3,685,278.

[52] **U.S. Cl.**.....**58/26,** 58/8, 58/23 D, 58/35, 58/85.5

[51] **Int. Cl.**.....**G04c 11/04,** G04c 9/00

[58] **Field of Search**.....58/7, 23 R, 23 V, 58/23 D, 24, 25, 26, 34, 35 R, 35 W, 425, 43

[56] **References Cited**

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Primary Examiner—Richard B. Wilkinson
Assistant Examiner—Edith C. Simmons Jackmon
Attorney—Lee C. Robinson Jr.

[57] **ABSTRACT**

A clock mechanism driven by a pulsed stepper motor and having planetary reduction gearing which provides a continuous but resilient connection between the motor and the minute hand of the clock at all times. The motor includes a permanent magnet rotor in direct driving relationship with the minute hand, and the rotor poles serve as a magnetic detent to hold the minute hand in discrete angular positions. The mechanism may be employed either in individual clocks or in the secondary clocks of a master-secondary clock system. In these latter embodiments the secondary clocks additionally include a pair of switches respectively controlled by the minute hand gearing and the hour hand gearing. The switches greatly facilitate the automatic resetting of the clocks in response to appropriate resetting signals from the master unit.

21 Claims, 9 Drawing Figures

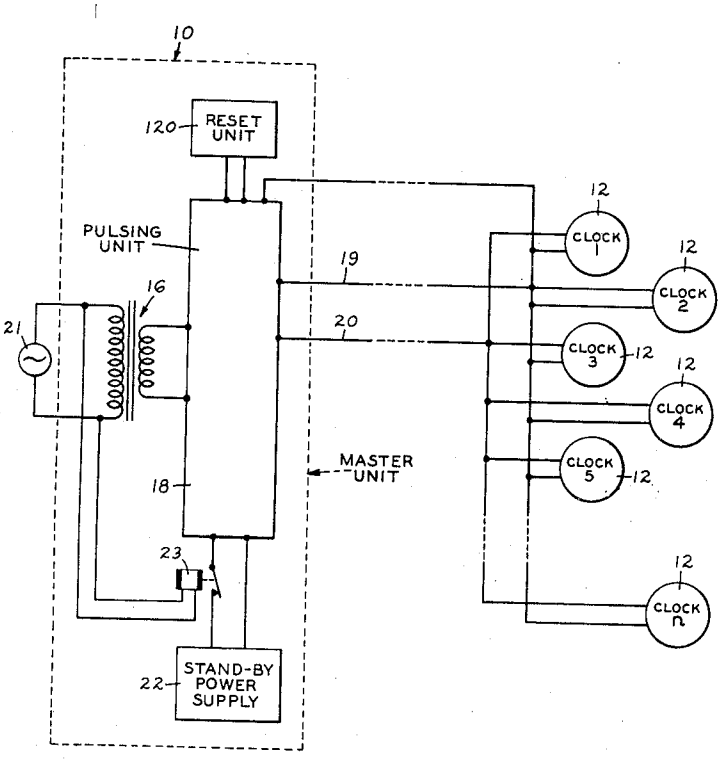


FIG.1.

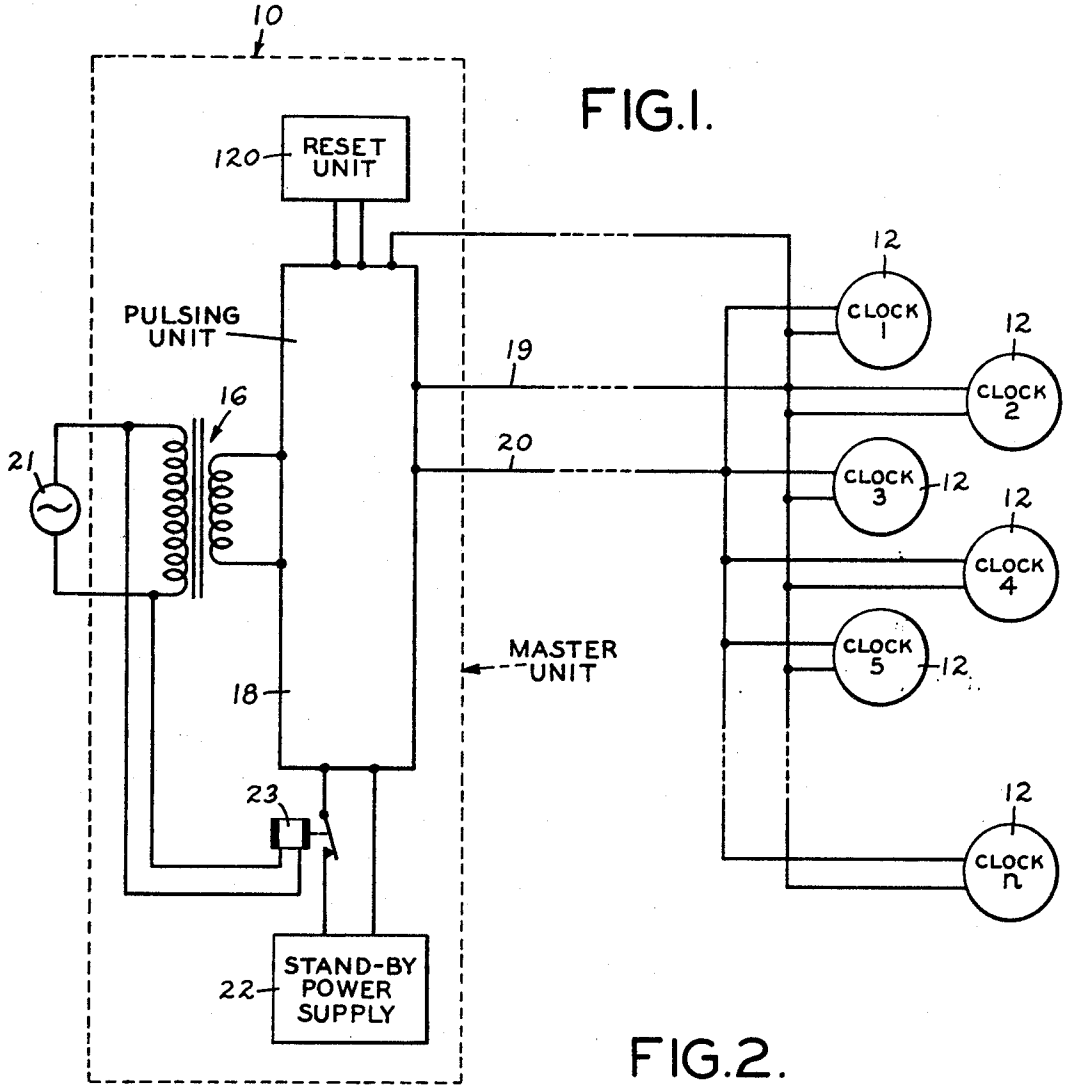

10
120
RESET UNIT
PULSING UNIT
16
21
19
20
18
23
MASTER UNIT
22
STAND-BY POWER SUPPLY
12
CLOCK 1
CLOCK 2
CLOCK 3
CLOCK 4
CLOCK 5
CLOCK n

FIG.2.

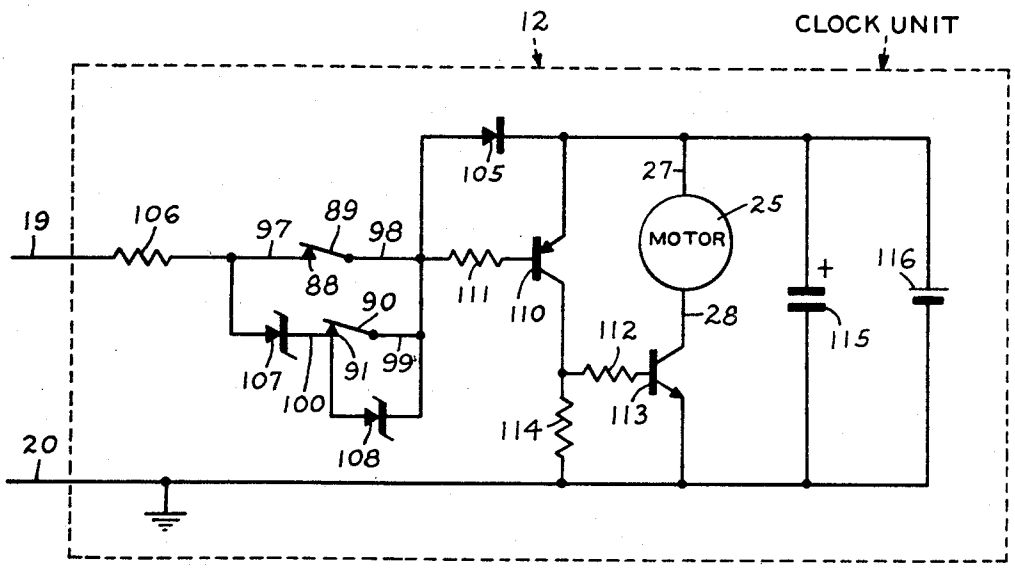

12
CLOCK UNIT
19
106
97
89
98
88
90
107
100
91
99
108
105
111
110
27
MOTOR
25
28
112
113
114
115
116
20

FIG.3.

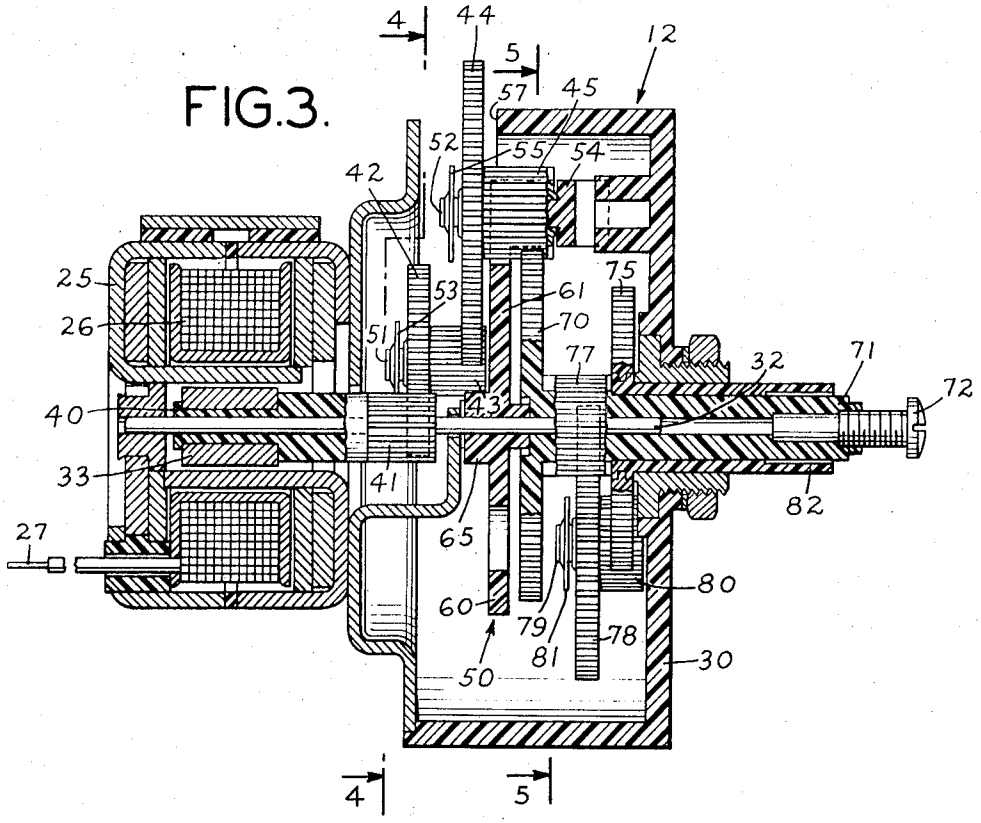

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44
5
12
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45
52
55
54
42
75
25
53
61
26
51
70
77
32
71
72
40
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33
41
82
27
65
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50
30
4
5

FIG.4.

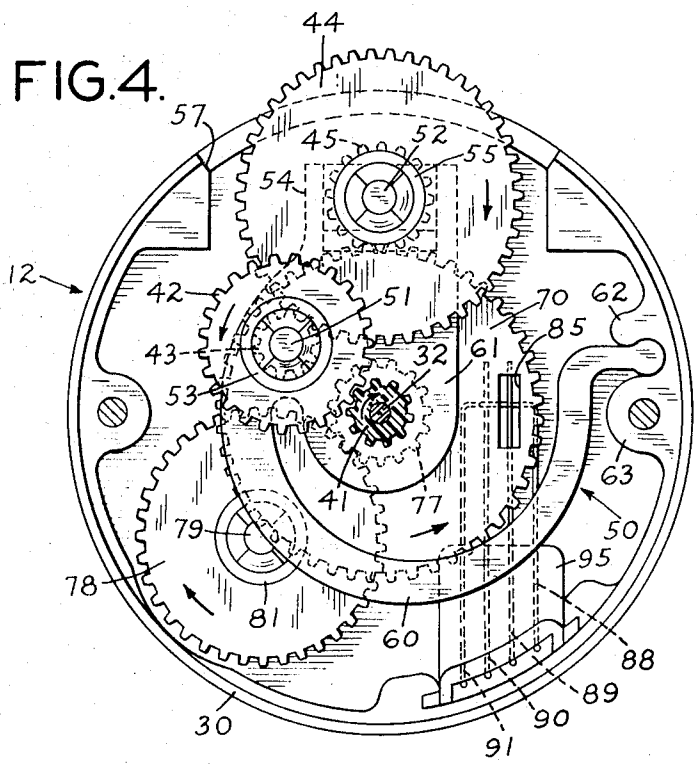

44
57
45
52
55
54
12
42
51
70
62
85
43
32
61
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41
77
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95
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60
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89
90
30
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FIG.5.

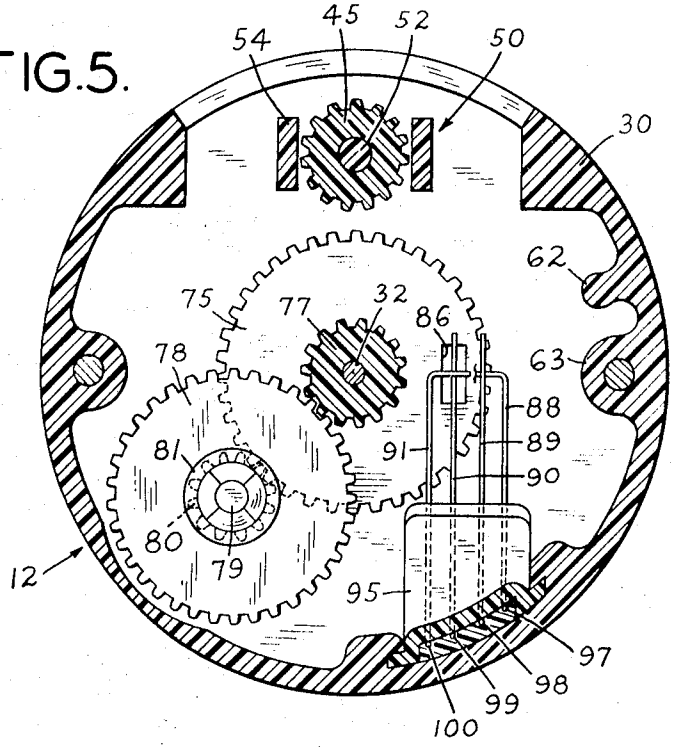
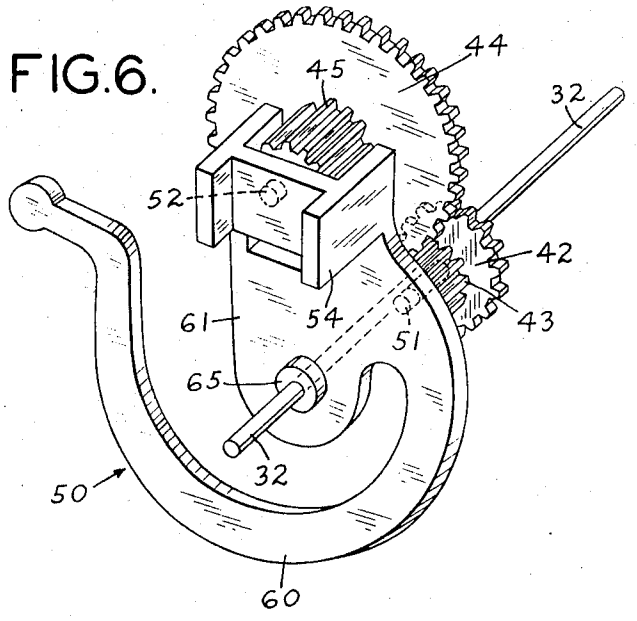

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30
62
75
77
32
86
78
63
88
89
91
90
81
80
79
12
95
97
98
99
100

FIG.6.


44
45
32
52
42
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61
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65
32
50
60

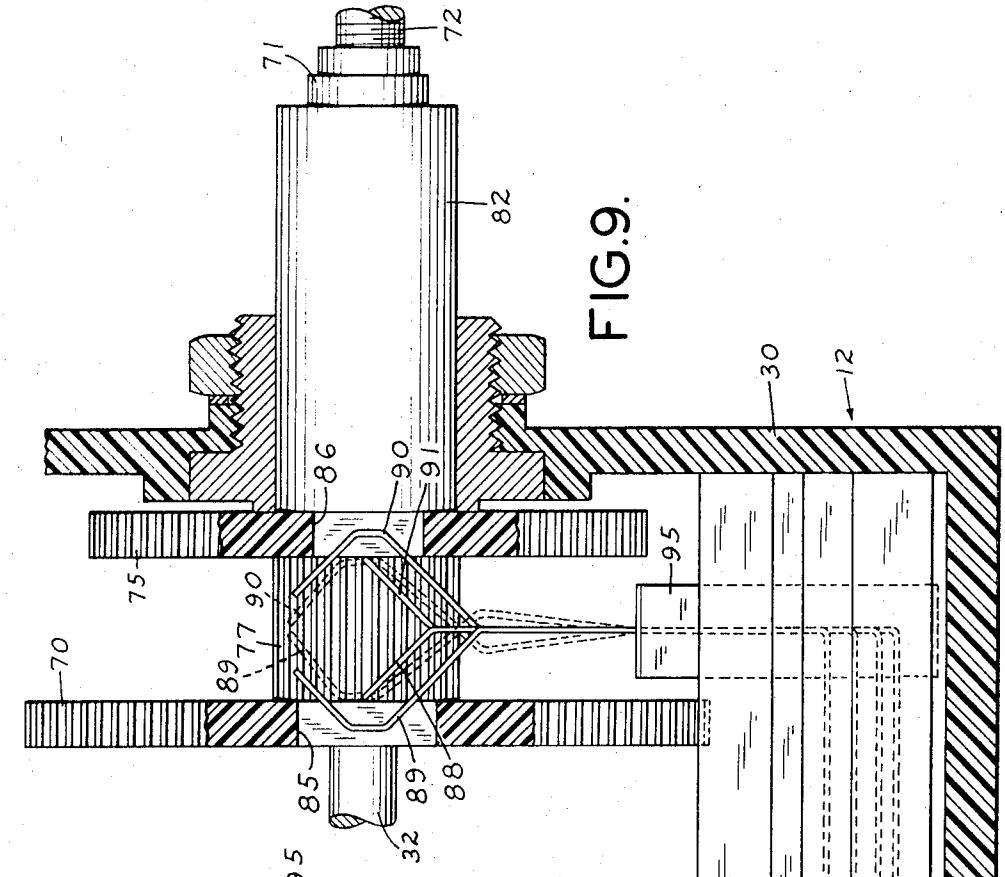


FIG.9.

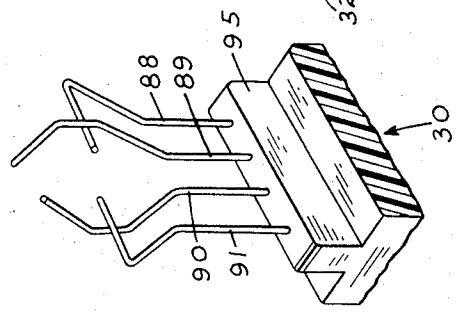


FIG.8.

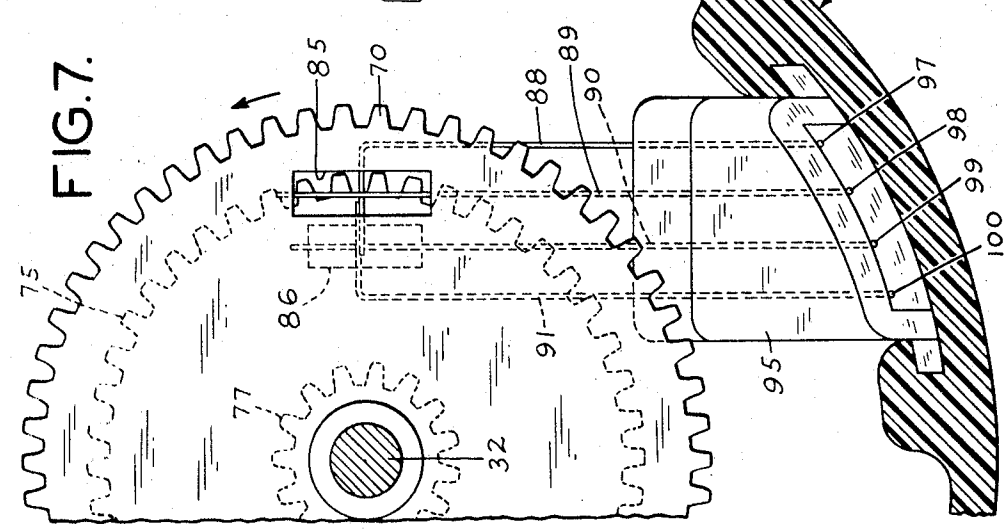


FIG.7.

CLOCK MECHANISM

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending application Ser. No. 45,609, filed June 12, 1970 by Arthur W. Haydon now U.S. Pat. No. 3,685,278.

BACKGROUND OF THE INVENTION

This invention relates to clock mechanisms and more particularly to a novel drive arrangement between the motor of the clock and the hands or other time indicating indicia.

The present invention, while of general application, is particularly well suited for use in clocks which are driven by pulsed stepper motors. One advantageous motor of this type is disclosed, for example, in Arthur W. Haydon U. S. Pat. No. 3,495,107 granted Feb. 10, 1970. Rather than being operated continuously, such motors are supplied with intermittent pulses of current and provide a significant reduction in the power consumption of the clocks when compared with more conventional synchronous motors. As more fully explained in Arthur W. Haydon U.S. Pat. No. 3,643,420 granted Feb. 22, 1972, the stepper motors also exhibit advantages when used to drive the secondary clocks in a master-secondary clock system.

Clock mechanisms of the type employed heretofore have exhibited certain disadvantages. For example, it often was necessary to provide a friction device, clutch or similar interruption in the drive train between the motor and the minute hand of the clock in order to facilitate resetting and to avoid other deleterious effects. In addition, in prior clocks of the type powered by stepper motors a continuous driving connection between the motor and the minute hand resulted in the application of a series of sharp impulses thereto, with the result that the minute hand as well as the second hand, if any, tended to vibrate or jiggle during each movement. Furthermore, in clock mechanisms of the type previously employed, problems arose because of the inertia of the reduction gears, hands, etc., with the result that the energy needed to properly drive the clock was excessive in many instances. These and other difficulties were compounded in cases in which the clocks were used in a clock system, employing a number of secondary clocks, and additional problems resulted from attempts to automatically reset the secondary clocks at periodic intervals to denote the correct time.

SUMMARY

One general object of this invention, therefore, is to provide a new and improved drive arrangement for a clock.

More specifically, it is an object of this invention to provide a clock mechanism which has a continuous driving connection between the motor and the hands or other time indicating indicia but which is arranged such that the clock may be readily reset to indicate the correct time.

Another object of the invention is to provide a clock mechanism of the character indicated which is driven by a pulsed stepper motor and includes novel reduction gearing to insure a smooth transfer of motion from the motor to the time indicating indicia.

An additional object of the invention is to provide such a clock mechanism in which the time indicating indicia is affirmatively held in successive discrete positions by the rotor of the motor.

A further object of the invention is to provide a master-secondary clock system in which all of the secondary clocks are automatically and simultaneously resettable to the correct time.

Still another object of the invention is to provide a clock mechanism utilizing comparatively simple mechanical and electrical elements which is economical to manufacture and thoroughly reliable in operation.

In one illustrative embodiment of this invention, the clock mechanism is disposed within a suitable housing or other support member and is driven by a two-wire stepper motor. The stepper motor is of the type which includes a permanent magnet two-pole rotor and an output pinion connected to the rotor. A minute hand gear and an hour hand gear are rotatably carried by a central shaft on the support member and are respectively affixed to the minute hand and the hour hand of the clock. These gears are interconnected by reduction gearing which maintains the minute hand gear in direct driving relationship with the hour hand gear. Interposed between the motor pinion and the minute hand is a resilient planetary reduction gear assembly which drives the minute hand gear in response to each successive increment of motion of the motor.

In accordance with one feature of the invention, in certain particularly important embodiments, the planetary reduction gear assembly serves as a direct but resilient connection between the output pinion of the motor and the minute gear. The resiliency of the planetary gearing enables an extremely smooth transfer of motion to the minute gear without unwanted vibration as a result of the successive increments of energy applied by the stepper motor.

In accordance with another feature of the invention, in several advantageous arrangements, the rotor poles of the motor provide a magnetic detent which holds the minute gear in successive discrete angular positions. Upon the automatic or manual resetting of the clock, the rotor poles automatically maintain the minute gear in its proper time indicating position.

In accordance with a further feature of certain preferred embodiments of the invention, the planetary reduction gearing is supported by a resilient arm member for limited orbital movement relative to the central shaft, and this arm member biases the gearing toward a particular orbital position with respect to the shaft. Upon the application of an input current pulse to the stepper motor, the planetary gearing is rotated in a direction to move it away from its particular orbital position against the bias of the resilient member. The resilient member thereupon returns the gearing toward the particular orbital position and advances the minute gear from one of its discrete angular positions to the succeeding angular position. The arrangement is such that the driving energy applied to the minute gear is continued after the termination of each input pulse, with the result that the minute gear receives a smooth flow of energy without unwanted vibration.

In accordance with a still further feature of the invention, in some good arrangements, the mechanism is provided with novel circuit means for detecting whether the minute and hour gears are in their correct angular positions, thus facilitating the automatic resetting of the gears in response to appropriate resetting signals.

The term "clock", as used herein, means any sort of time indicating, controlling or recording mechanism such as a clock with a dial and hand, a digital clock, a time switch, a repeat cycle timer, an elapsed time indicator, a chart drive, or other instrument where the essential function of the mechanism is dependent on timing intelligence.

The present invention, as well as further objects and features thereof, will become more fully apparent from the following detailed description of certain preferred embodiments, when read with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a clock system in accordance with an illustrative embodiment of the invention.

FIG. 2 is a schematic wiring diagram of the electrical circuit for one of the clocks of FIG. 1.

FIG. 3 is a vertical sectional view of a clock mechanism in accordance with an illustrative embodiment of the invention which is suitable for use in the clock system of FIG. 1.

FIG. 4 is a vertical sectional view taken along the line 4—4 in FIG. 3.

FIG. 5 is a vertical sectional view taken along the line 5—5 in FIG. 3.

FIG. 6 is a fragmentary perspective view of certain of the components shown in FIGS. 3–5.

FIG. 7 is an enlarged fragmentary sectional view similar to a portion of FIG. 4 but with certain parts omitted for purposes of clarity.

FIG. 8 is a fragmentary perspective view of the switch contact structure illustrated in FIG. 7.

FIG. 9 is an enlarged fragmentary sectional view similar to a portion of FIG. 3 but showing certain additional parts.

DESCRIPTION OF CERTAIN PREFERRED EMBODIMENTS

Before describing the construction and mode of operation of the driving mechanisms for the individual clocks, there will first be given a brief discussion of a master-secondary clock system with which the clock mechanisms are particularly useful. Following the description of the mechanisms themselves, there will be presented a discussion of the way in which the clocks are reset when used in a system of this character.

THE MASTER-SECONDARY CLOCK SYSTEM

Referring to FIG. 1 of the drawings, there is shown a clock system which comprises a master unit **10** and a series of remotely located secondary units **12.** The master unit **10** may or may not include appropriate time-indicating indicia, while each of the secondary units is in the form of a clock. The unit **10** comprises a voltage reducing transformer **16** and a pulsing circuit **18** having a pair of output leads **19** and **20** which are connected to the secondary clocks **12.** The pulsing circuit **18** is effective to generate clock pulses at a uniform frequency dependent on the frequency of an alternating current source **21** such as that available from the local power company. In the illustrated embodiment, the source **21** comprises a standard 110 volt, 60 cycle a.c. power supply, and during normal operation the pulsing circuit **18** is constructed to send out a +6 volt d.c. signal over the leads **19** and **20.** The transmitted signal is interrupted once per minute to provide negative going pulses of from +6 volts to 0 volts. These pulses are simultaneously applied to each of the secondary clocks **12** to advance the hands of the clocks in accordance with the timing intelligence of the source **21.**

An auxiliary or stand-by power supply **22** is maintained in electrical circuit relationship with the pulsing circuit **18.** Although a wide variety of stand-by power supplies may be employed for this purpose, one particularly advantageous supply is disclosed in U.S. Pat. application Ser. No. 837,774 filed June 30, 1969 by Arthur W. Haydon. Power supplies of this character include a battery or other direct current source and are effective to produce an alternating wave form at an extremely precise and constant frequency. The connection between the supply **22** and the pulsing circuit **18** includes a normally closed relay **23.** The relay **23** is normally maintained in its energized or open condition by the alternating current signal from the source **21,** thus preventing the transmission of auxiliary power to the pulsing circuit **18.** In the event of a power failure or other interruption in the signal from the source **21,** the relay moves to its closed position to furnish stand-by power from the supply to the pulsing circuit. With this arrangement, the individual secondary clocks **12** continue to advance during the interruption.

THE CLOCK DRIVE MECHANISMS

As best shown in FIG. **3,** each of the secondary clocks **12** includes a pulsed stepper motor **25.** The motor **25** illustratively comprises a two-wire stepper motor of the type disclosed in Haydon U.S. Pat. No. 3,495,107 referred to above, although other types of two- and three- wire stepper motors also may be employed with good results. The motor **25** is provided with an energizing winding **26** having input leads **27** and **28** which are electrically connected in the secondary clock circuit of FIG. **2** in a manner that will become more fully apparent hereinafter.

The stepper motor **25** is externally mounted on one end of a generally cylindrical housing member **30.** A stationary shaft **32** is centrally located within the housing **30,** and this shaft protrudes from the housing adjacent the motor **25** to provide support for a rotor **33.** The rotor **33** is in the form of a sleeve of ceramic magnetic material which is permanently magnetized to provide a single pair of rotor poles. In a manner more fully described in the above noted Haydon U.S. Pat. No. 3,495,107, the rotor turns through a complete 360° revolution in response to each pulse applied to the energizing winding **26.**

The rotor **33** is affixed to a central sleeve **40** which is rotatably carried on the shaft **32** and is integral with a drive pinion **41.** The sleeve **40** and the pinion **41** are made from an acetal resin such as Delrin, for example, a registered trademark of E.I. duPont de Nemours & Company. The pinion **41** protrudes into the housing **30** and is in meshing engagement with a planetary reduction gear **42.** A pinion **43** is integrally formed with the gear **42** and meshes with a secondary planetary reduction gear **44** having an integrally formed pinion **45.** These gears and pinions, as well as the remaining gears and pinions within the clock mechanism, similarly are fabricated from Delrin acetal resin or other suitable material.

As best shown in FIG. 6, the planetary reduction gear 42 and its attached pinion 43, and the planetary reduction gear 44 and its attached pinion 45, are supported by a resilient arm member indicated generally at 50. The arm member 50 is of arcuate configuration and includes two integrally formed stub shafts 51 and 52 which extend in directions parallel to the central shaft 32 in spaced orbital relationship therewith. The stub shaft 51 is located intermediate the ends of the arm member 50 and rotatably carries the planetary gear 42 and the pinion 43, these components being held in place on the shaft by a push-on fastener 53 (FIG. 4). The stub shaft 52 is disposed at the outer end of the arm member 50 on an offset portion 54, and the planetary gear 44 and attached pinion 45 are rotatably carried by the shaft 52 and are similarly held in place by a push-on fastener 55. The gear 44 protrudes through an opening 57 in the housing 30, for purposes that will become more fully apparent hereinafter.

The arm member 50 is fabricated from Delrin acetal resin or other material which is relatively stiff but exhibits a certain amount of resiliency. The member 50 includes a comparatively thin arcuate portion 60 and a wider, more rigid portion 61. One end of the portion 60 is rigidly held between two inwardly extending protrusions 62 and 63 which are integrally formed on the interior of the housing 30. The portion 60 extends from the protrusions 62 and 63 around the central shaft 32 in spaced relationship therewith, and its opposite end merges with the portion 61. This latter portion is provided with an integral bushing 65 for the shaft 32. The portion 61 extends in a radial direction with respect to the shaft 32 and supports the stub shaft 51 for the planetary gear 42 and attached pinion 43 and the offset portion 54 carrying the stub shaft 52 for the planetary gear 44 and attached pinion 45. The arrangement is such that the portion 61 maintains the respective planetary gear and pinion assemblies at fixed but different radial distances from the shaft 32, while the flexibility of the portion 60 permits each assembly to move orbitally relative to the shaft against the resilient bias of the arm member. The planetary gear and pinion assemblies are thus resiliently biased toward particular orbital positions (the positions shown in FIG. 4) with respect to the shaft.

Disposed around the central shaft 32 in meshing engagement with the pinion 45 is a timing or minute hand gear 70. As a result of the planetary gearing on the comparatively rigid portion 61 of the arm member 50, the output pinion 41 of the stepper motor 25 is maintained in direct driving relationship with the minute gear 70 at all times. The various gear ratios are such that the gear 70 rotates through an angle of six degrees in response to each complete revolution of the output pinion 41. In cases in which the motor winding 26 is pulsed at a rate of once per minute, the rotor 33 and the pinion 41 rotate 360° during each minute, with the result that the gear 70 turns through a complete revolution once per hour. A minute hand sleeve 71 is integrally formed with the gear 70, and this sleeve is disposed around the central shaft 32 and protrudes from the side of the housing 30 opposite that adjacent the motor 25. The protruding end of the sleeve 71 is provided with a self-tapping screw 72 which serves to affix the minute hand (not shown) to the sleeve.

An hour gear 75 is rotatably positioned around the minute hand sleeve 71 between the minute gear 70 and the adjacent wall of the housing 30. The hour gear 75 is driven by the minute gear 70 through reduction gearing which comprises a pinion 77 integral with the sleeve 71, a planetary gear 78 rotatably carried on a stub shaft 79 and a pinion 80 integral with the gear 78. The stub shaft 79 protrudes from the adjacent inner wall of the housing 30 in spaced parallel relationship with the central shaft 32 and is provided with a push-on fastener 81 to hold the gear and pinion in place. The minute pinion 77 meshes with the planetary gear 78 and the pinion 80 meshes with the hour gear 80 to maintain the minute gear in direct driving relationship with the all times. The gear ratios are such that the hour gear rotates through an angle of 30° in response to each complete revolution of the minute gear. A sleeve 82 is affixed to the hour gear, and this sleeve protrudes from the housing 30 in coaxial relationship with the minute hand sleeve 71 and the central shaft 32. As will be understood, an hour hand (not shown) is suitably secured to the sleeve 82.

DRIVE MECHANISM OPERATION

Upon the application of each successive current pulse to the energizing winding 26 of the stepper motor 25, the rotor 33 of the motor turns through a complete revolution. The output pinion 41 similarly rotates through a complete revolution about the central shaft 32, the pinion being driven in a clockwise direction, as viewed in FIG. 4. The pinion 41 drives the planetary gear 42 and the attached pinion 43 in a counterclockwise direction, and this latter pinion in turn drives the planetary gear 44 and the attached pinion 45 clockwise.

Particularly during the initial portion of the rotation of the planetary reduction gear 44 and the attached pinion 45, the inertia of the succeeding gears and pinions in the train, and particularly the minute and hour hands of the clock, tend to hold the minute gear 70 stationary. As a result, the rotational axis of the planetary gear 44 and the pinion 45, as well as the rotational axis of the planetary gear 42 and the pinion 43, undergo limited orbital movement relative to the central shaft 32 against the resilient bias provided by the flexible arm member 50. This movement carries the planetary gears and pinions to the right (clockwise) from the particular orbital positions illustrated in FIG. 4. Thereafter, the stored energy in the arm member 50 returns the planetary gears and pinions to their particular orbital positions, and the pinion 45 acts on the minute gear 70 to advance the gear through a six degree angle. The minute gear in turns moves the sleeve 71 and the minute hand of the clock to the next discrete position corresponding to the succeeding minute.

As the minute gear 70 steps forward, the pinion 77 thereon drives the reduction gear 78 and the attached pinion 80 to advance the hour gear 75. The reduction gear train comprising the gear 78 and the pinion 80 is in meshing engagement with both the minute gear 70 and the hour gear 75 at all times, thus maintaining the minute gear in direct driving relationship with the hour gear. The hour gear, its attached sleeve 82 and the hour hand of the clock complete one revolution every 12 hours in the usual way.

As indicated heretofore, the planetary reduction gearing carried by the resilient arm member 50 is in continuous meshing engagement with both the motor pinion 41 and the minute gear 70 at all times during the

rotation of the minute gear, thus maintaining the pinion **41** and the attached permanent magnet rotor **33** in direct driving relationship with the gear **70.** The poles of the rotor **33** provide a magnetic detent which holds the minute gear **70** and hence the minute hand in discrete angular positions relative to the central shaft **32** which correspond to the successive minutes of the clock. In order to manually reset the clock to the correct time, the protruding portion of the planetary reduction gear **44** is turned in the desired direction to bring the minute hand into its approximate correct position. Because of the magnetic detent provided by the rotor **33,** the minute hand thereupon automatically moves to its proper time indicating position.

THE RESETTING MECHANISM

In cases in which the clock mechanism is arranged for automatic resetting at preselected intervals, the minute gear **70** and the hour gear **75** are respectively provided with rectangular openings **85** and **86** (FIGS. 7 and 9) at preselected positions. In the illustrated embodiment the opening **85** in the minute gear **70** is oriented with respect to the minute hand of the clock at the **58** minute position, and the opening passes this position once each hour. The opening **86** in the hour gear **75** is located at the 2:58 position, and for a 12 hour clock the opening passes this position twice a day.

The minute gear opening **85** cooperates with a pair of normally closed contact wires **88** and **89,** and the hour gear opening **86** cooperates with a pair of normally closed contact wires **90** and **91.** The wires **88** and **91** are stationary, while the wires **89** and **90** are resiliently biased toward the respective gears **70** and **75** and are arranged to move into and out of the opening **85** or **86** as the corresponding gear rotates. The movement of the wire **89** or **90** into the opening **85** or **86** serves to carry the wire away from its adjacent wire **88** or **91** to open an electrical circuit.

The contact wires **88, 89, 90** and **91** are supported by a terminal block **95** which is integrally formed with the adjacent portion of the housing **30.** The wires **88, 89, 90** and **91** are respectively connected within the block **95** to corresponding leads **97, 98, 99** and **100.** These leads are arranged in the secondary clock circuit shown schematically in FIG. **2.** The lead **97** is connected through a resistor **106** to the input line **19,** and the lead **98** is connected to the anode of a diode rectifier **105,** the cathode of which leads to the motor terminal **27.** The minute gear contacts **88** and **89** are thus in series with the motor **25.** The hour gear contacts **90** and **91** are in parallel with the minute gear contacts **88** and **89.** The lead **99** for the contact **90** is connected to the lead **98** for the contact **89,** while the lead **100** for the contact **91** is connected to the cathode of a Zener diode **107.** the anode of the diode **107** is connected to the lead **97** for the contact **88.** A second Zener diode **108** is connected across the contacts **90** and **91** with its cathode connected to the lead **99** and its anode connected to the lead **100.**

The base of a P-N-P transistor **110** leads through a resistor **111** to the common terminal of the switch contacts **89** and **90.** The emitter of the transistor **110** is connected to the cathode of the diode **105,** while the collector is connected through a resistor **112** to the base of an N-P-N transistor **113** and through a biasing resistor **114** to the grounded input lead **20.** The emitter of this latter transistor likewise is connected to the input lead **20,** and the collector is connected to the motor terminal **28.** The circuit additionally includes a condenser **115** connected between the motor terminal **27** and the emitter of the transistor **113** and a low voltage battery **116** in parallel with the condenser.

CIRCUIT OPERATION

The pulsing unit **18** (FIG. **1**) normally maintains a low level direct current signal, illustratively +6 volts, across the leads **19** and **20.** With the minute contacts **88** and **89** and the hour contacts **90** and **91** in their closed positions, the incoming signal maintains the transistor **110** in a nonconducting condition and charges the condenser **115** through the diode **105.** The transistor **113** also is nonconducting at this point to break the circuit for the motor **25.**

As indicated heretofore, the incoming signal is interrupted once per minute to provide negative going pulses to the individual clock mechanisms. Upon the receipt of each of these pulses, the transistor **110** is rendered conducting and the transistor **113** also conducts to connect the condenser **115** across the motor **25** and apply a sharp stepping pulse to the motor winding. The rotor of the motor **25** steps a full 360° in response to the applied pulse to advance the clock mechanism one minute in the manner described above.

The master unit **10** additionally includes a reset unit indicated generally at **120.** The unit **120** is arranged to send out particular resetting pulses over the leads **19** and **20** at preselected intervals corresponding to the times at which the secondary clocks **12** are to be reset. If, for example, the clocks **12** are to be reset at **58** minutes after each hour, in the illustrated embodiment the unit **120** causes the generation of a 30 second pulse train at the rate of 30 pulses per second beginning at the 58th minute. This pulse train is produced by shorting the low voltage d.c. signal on the leads **19** and **20** at the selected rate.

For those secondary clocks **12** which are on time at the 58th minute, the contact wire **89** (FIGS. 7–9) is located within the minute gear opening **85** to break the circuit between the wires **88** and **89.** The Zener diode **107** (FIG. **2**) is thus connected in series with the triggering transistor **110** to block the triggering of the transistor and momentarily prevent the further advance of the minute hand. For those clocks which are too fast, a similar blocking occurs. If a particular clock is too slow, the 30 pulse per second signal from the master unit rapidly steps the rotor of the motor **25** until such time as the minute hand gear for that clock reaches the 58 minute position, at which point the contacts **88** and **89** open and the diode **107** blocks the further pulsing of the motor.

At 58 minutes and 30 seconds after each hour, the train of resetting pulses from the master unit is arrested, and the normal low voltage d.c. signal appears across the leads **19** and **20.** At 59 minutes after each hour, the reset unit **120** sends a single −12 volt pulse over the leads **19** and **20** to each of the secondary clocks. The voltage of this pulse is outside the operating range of the Zener diode **107,** and the pulse accordingly is transmitted through the diode and the closed hour hand contacts **90** and **91** to turn on the transistor **110.** The transistor **110** triggers the transistor **113** to switch it to its conducting condition and thereby apply a pulse from the condenser **115** to the motor **25.** The minute hands for all of the clocks are thus simulta-

neously advanced from the 58 minute position to the 59 minute position. Thereafter, the application of the successive minute pulses to the clocks continues in the manner described heretofore.

Similarly, at 2:58 a.m. and p.m., the reset unit **120** transmits a train of 30 pulses per second to the secondary clocks **12** for 30 seconds. These latter pulses comprise voltage variations across the leads **19** and **20** of from +6 volts to −6 volts. If both the minute hand contacts **88** and **89** and the hour hand contacts **90** and **91** are in their open positions, indicating that the minute and hour hands are at the correct time or are too fast, the incoming train of pulses is blocked by the series-connected Zener diodes **107** and **108.** If, on the other hand, the contacts **88** and **89** are closed, representing a slow minute hand, the resetting pulses trigger the secondary clock circuit and rapidly advance the rotor of the motor **25** until the minute hand reaches the correct position. Should the hour hand contacts **90** and **91** be closed, the resetting pulses likewise trigger the circuit to advance the rotor until the hour hand reaches its correct position. In this latter situation, if the contacts **88** and **89** are closed the resetting pulses are transmitted across the contacts to the base of the transistor **110,** while if the contacts **88** and **89** are open the pulses proceed to the transistor through the Zener diode **107** and the contacts **90** and **91.**

At 2:59 a.m. and p.m., a single −12 volt pulse is transmitted from the reset unit **120** over the leads **19** and **20** to the secondary clocks **12.** The pulse passes through the series-connected Zener diodes **107** and **108** to simultaneously advance the minute hands of all of the clocks and thus close the minute and hour hand contacts and restore the system to normal operation.

The reset rate of thirty pulses per second is 1800 times the normal rate of one pulse per minute. With this arrangement, the maximum amount of time required to reset the minute hand is at most less than 2 seconds, depending upon the amount of error, and the maximum time required to reset the hour hand as well as the minute hand is less than 30 seconds. Of course, many types of clock systems exhibit sufficient timing accuracy that the reset rate may be substantially less than 30 pulses per second, and some systems may be sufficiently accurate that the resetting circuitry may be dispensed with entirely.

The current applied to the condenser **115** after each incoming pulse from the master unit **10** should be sufficient to recharge the condenser preparatory to the receipt of the next pulse. During resetting and in other cases in which the line current from the master unit may be at too low a level for this purpose, such as when there are a large number of secondary clocks on the line, the battery **116** provides the desired recharging current. For comparatively low reset pulse rates or in other situations in which sufficient charging current is available from the master unit, the battery **116** may be eliminated from the circuit without deleterious effect.

In the illustrated embodiment of the invention the minute hand contacts **88** and **89** and the hour hand contacts **90** and **91** are opened in response to the movement of the gear openings **85** and **86** (FIG. 7) into their preselected positions. In other advantageous arrangements the contacts may be in the form of reed switches, for example, and the openings **85** and **86** may be replaced by small permanently magnetized elements at the selected positions on the minute gear **70** and the hour gear **75.** The reed switches are normally closed but are opened as the magnetic elements move into juxtaposition therewith.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions of excluding equivalents of the features shown and described, or portions thereof, it being recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. In a clock, in combination:
a support member;
drive means mounted on the support member;
a shaft carried by the support member;
timing means rotatable about the axis of the shaft;
planetary reduction means interconnecting the drive means and the timing means for maintaining the drive means in direct driving relationship with the timing means at all times during its rotation;
means for supporting the planetary reduction means for limited orbital movement relative to the shaft and for resiliently biasing said planetary reduction means toward a particular orbital position with respect thereto; and
means for actuating the drive means to move the planetary reduction means away from said particular orbital position against its resilient bias and to rotate the timing means.

2. In a clock as defined in claim **1,** the drive means comprising a pulsed stepper motor having a rotor including a plurality of permanently magnetized rotor poles, the rotor poles providing a magnetic detent to hold the timing means in discrete angular positions relative to said shaft.

3. In a clock, in combination:
a support member;
drive means mounted on the support member;
a shaft carried by the support member;
timing means rotatable about the axis of the shaft;
planetary reduction means in continuous engagement with both the drive means and the timing means at all times during its rotation, to maintain the drive means in direct driving relationship with the timing means;
means for rotatably supporting the planetary reduction means for limited orbital movement relative to the shaft and for resiliently biasing said planetary reduction means toward a particular orbital position with respect thereto; and
means for actuating the drive means to rotate the planetary reduction means in a direction to move the same away from said particular orbital position against its resilient bias, the planetary reduction means thereupon returning toward said orbital position to advance the timing means.

4. In a clock, in combination:
a support member;
drive means mounted on the support member and having an output pinion;
a central shaft carried by the support member;
timing gear means rotatable about the axis of the central shaft;
planetary reduction gearing in continuous meshing engagement with both the output pinion and the timing gear means at all times during its rotation,

to maintain the pinion in direct driving relationship with the timing gear means;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto; and

means for actuating the drive means to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resilient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to advance the timing gear means.

5. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet rotor and an output pinion connected to the rotor;

a shaft carried by the support member;

timing gear means rotatable about the axis of the shaft;

planetary reduction gearing in continuous meshing engagement with both the output pinion and the timing gear means at all times during its rotation, to maintain the pinion in direct driving relationship with the timing gear means, the rotor of the motor providing a magnetic detent to hold the timing gear means in discrete angular positions relative to the shaft;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto; and

means for applying electrical pulses to the stepper motor to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resilient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to move the timing gear means from one of its discrete angular positions to an adjacent angular position.

6. In a clock, in combination:

a support member;

drive means mounted on the support member;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction means interconnecting the drive means and the minute gear means;

means for supporting the planetary reduction means for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction means toward a particular orbital position with respect thereto; and

means for actuating the drive means to move the planetary reduction means away from said particular orbital position against its resilient bias and to rotate the minute gear means.

7. In a clock as defined in claim **6**, in which the means for supporting the planetary reduction means comprises a flexible arm member mounted on said support member.

8. In a clock as defined in claim **6**, in which the planetary reduction means comprises a plurality of planetary gears supported at different distances from the central shaft.

9. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet rotor and an output pinion connected to the rotor;

a shaft carried by the support member;

minute gear means rotatable about the axis of the shaft;

hour gear means rotatable about the axis of the shaft;

means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction means interconnecting the output pinion and the minute gear means;

resilient means for supporting the planetary reduction means for limited orbital movement relative to the shaft and for resiliently biasing said planetary reduction means toward a particular orbital position with respect thereto; and

means for applying electrical pulses to the stepper motor to move the planetary reduction means away from said particular orbital position against the bias of the resilient means and to rotate the minute gear means.

10. In a clock as defined in claim **9**, which further comprises

means for applying resetting pulses to the stepper motor at preselected intervals; and

means for disabling the minute gear means during the application of the resetting pulses when the minute gear means is in its correct angular position.

11. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member and an output pinion driven by the motor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in meshing engagement with both the output pinion and the minute gear means, to maintain the pinion in direct driving relationship with the minute gear means;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto; and

means for applying electrical pulses to the stepper motor to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resil-

ient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to rotate the minute gear means.

12. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet two-pole rotor and an output pinion connected to the rotor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in continuous meshing engagement with both the output pinion and the minute gear means at all times during its rotation, to maintain the pinion in direct driving relationship with the minute gear means, the rotor poles of the motor providing a magnetic detent to hold the minute gear means in discrete angular positions relative to the central shaft;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto; and

means for applying electrical pulses to the stepper motor to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resilient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to move the minute gear means from one of its discrete angular positions to an adjacent angular position.

13. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member and an output pinion driven by the motor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in meshing engagement with both the output pinion and the minute gear means, to maintain the pinion in direct driving relationship with the minute gear means;

means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto;

means for applying clock pulses to the stepper motor to move the planetary reduction gearing away from said particular orbital position against its resilient bias and to rotate the minute gear means and the hour gear means at timing speed; and

means for applying resetting pulses to the stepper motor to rotate at least one of said gear means at a speed higher than said timing speed.

14. In a clock as defined in claim 13 which further comprises

switching means controlled by said one gear means for disabling the stepper motor when said one gear means is in a particular angular position; and

means for thereafter enabling the stepper motor to condition the same for the receipt of successive clock pulses.

15. In a clock as defined in claim 14, in which said one gear means is the minute gear means.

16. In a clock as defined in claim 14, in which the switching means comprises a pair of normally closed contacts, and said one gear means includes actuating means for opening said contacts when the one gear means is in said particular angular position.

17. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet rotor and an output pinion connected to the rotor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in meshing engagement with both the output pinion and the minute gear means, to maintain the pinion in direct driving relationship with the minute gear means;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto;

means for applying clock pulses to the stepper motor to move the planetary reduction gearing away from said particular orbital position against the bias of the resilient means and to rotate the minute gear means and the hour gear means at timing speed;

means for applying resetting pulses to the stepper motor to rotate the minute gear means and the hour gear means at a speed higher than said timing speed; and

means including first and second switch contacts respectively controlled by the minute gear means and the hour gear means for disabling the stepper motor when the corresponding gear means is in a selected angular position.

18. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet rotor and an output pinion connected to the rotor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in continuous meshing engagement with both the output pinion and the minute gear means at all times during its rotation, to maintain the pinion in direct driving relationship with the minute gear means, the rotor poles of the motor providing a magnetic detent to hold the minute gear means in discrete angular positions relative to the central shaft;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto;

means for applying clock pulses to the stepper motor to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resilient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to move the minute gear means at timing from one of its discrete angular positions to an adjacent angular position; and

means for applying resetting pulses to the stepper motor to rotate the minute gear means at a speed higher than said timing speed.

19. In a clock as defined in claim **18,** in which the resilient means includes a flexible arm member mounted on the support member, and in which the planetary reduction gearing includes a plurality of planetary gears carried by the arm member.

20. In a clock as defined in claim **19,** in which the planetary gears are carried by the arm member at different distances from the central shaft.

21. In a clock, in combination:

a support member;

drive means including a pulsed stepper motor mounted on the support member, the motor having a permanent magnet two-pole rotor and an output pinion connected to the rotor;

a central shaft carried by the support member;

minute gear means rotatable about the axis of the central shaft and having an opening in a preselected position thereon;

hour gear means rotatable about the axis of the central shaft;

first reduction gearing in meshing engagement with both the minute gear means and the hour gear means for maintaining the minute gear means in direct driving relationship with the hour gear means;

planetary reduction gearing in continuous meshing engagement with both the output pinion and the minute gear means at all times during its rotation, to maintain the pinion in direct driving relationship with the minute gear means, the rotor poles of the motor providing a magnetic detent to hold the minute gear means in discrete angular positions relative to the central shaft;

resilient means for rotatably supporting the planetary reduction gearing for limited orbital movement relative to the central shaft and for resiliently biasing said planetary reduction gearing toward a particular orbital position with respect thereto;

means for applying clock pulses to the stepper motor to rotate the planetary reduction gearing in a direction to move the same away from said particular orbital position against the bias of the resilient means, the resilient means thereupon returning said planetary reduction gearing toward said orbital position to move the minute gear means at timing speed from one of its discrete angular positions to an adjacent angular position;

means for applying resetting pulses to the stepper motor to rotate the minute gear means at a speed higher than said timing speed;

switching means including a contact member movable into the opening in the minute gear means for disabling the stepper motor when the minute gear means is in its correct timing position; and

means for thereafter applying an enabling pulse to the stepper motor to condition the same for the receipt of said clock pulses.

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