Oct. 22, 1968 KIYOSHI BANSHO 3,407,344

ELECTRONIC TIMEKEEPER

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Fig. 1

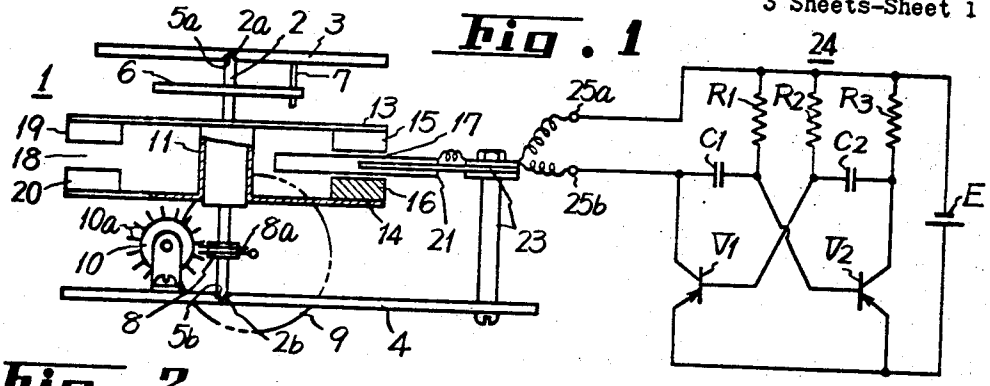


Fig. 2

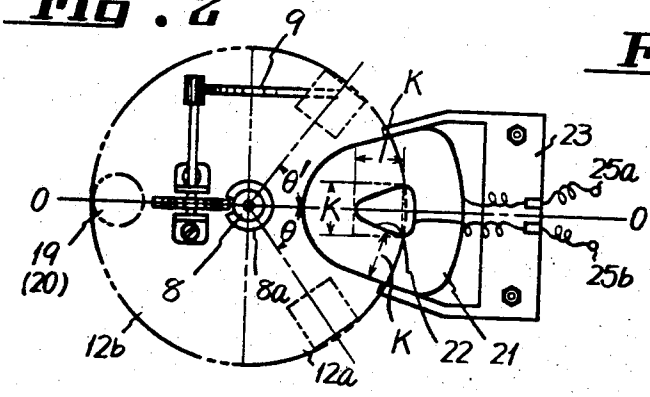


Fig. 4

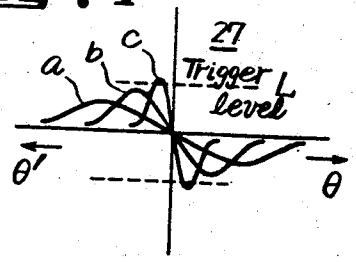
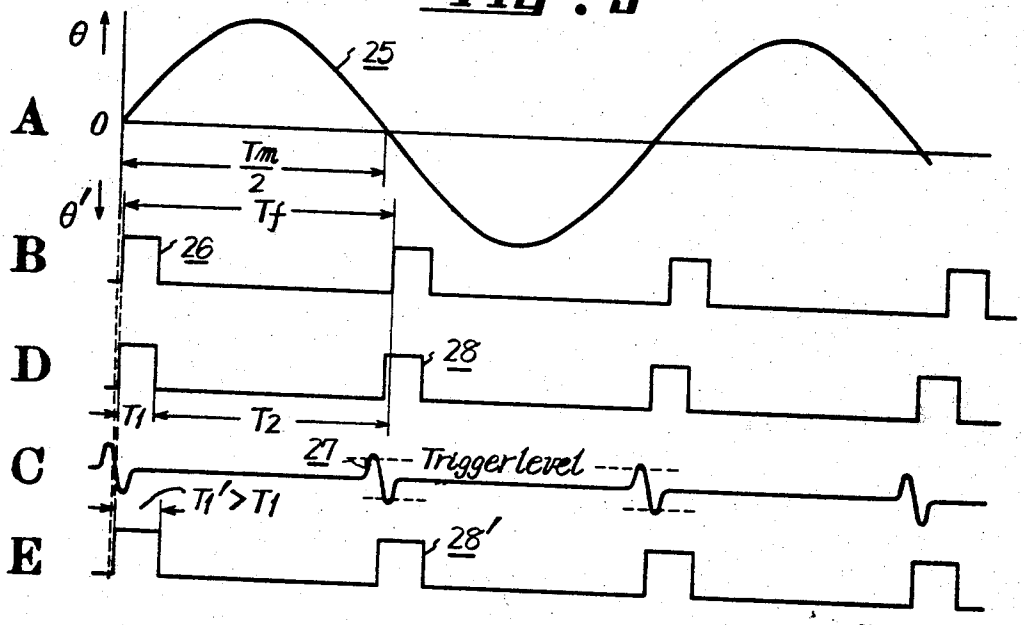


Fig. 3



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Fig. 5

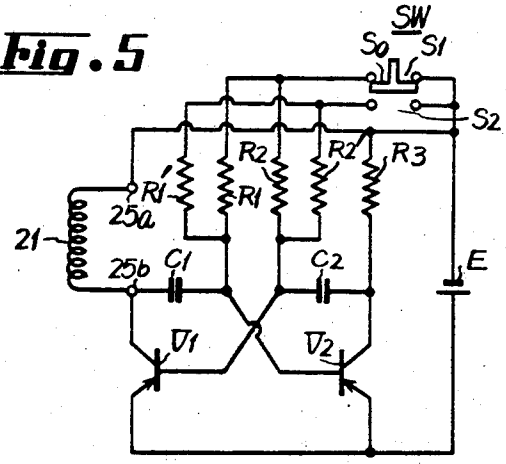


Fig. 6

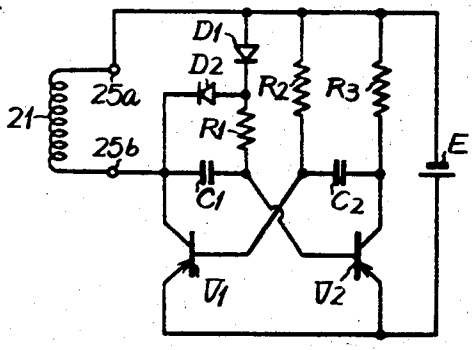


Fig. 7

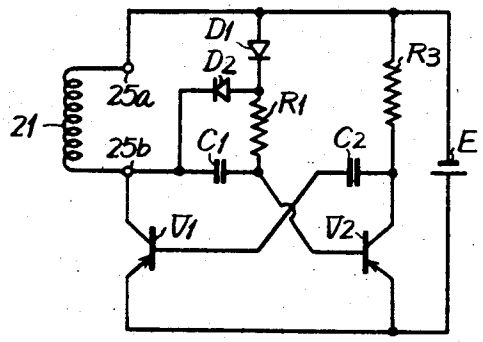


Fig. 8

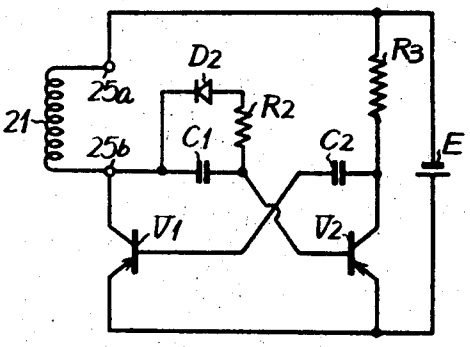


Fig. 9

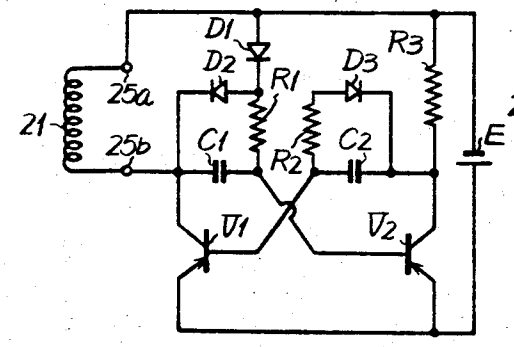
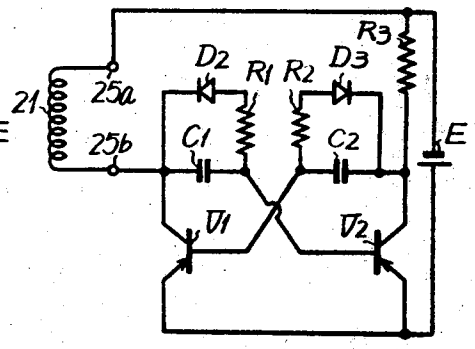


Fig. 10



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Fig. 11

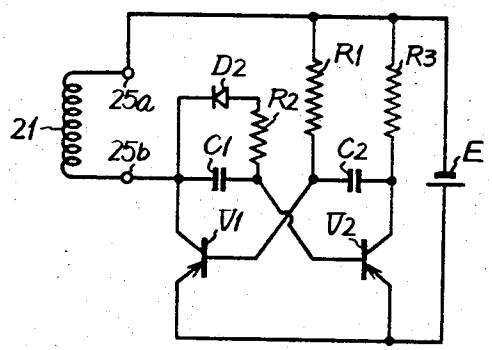
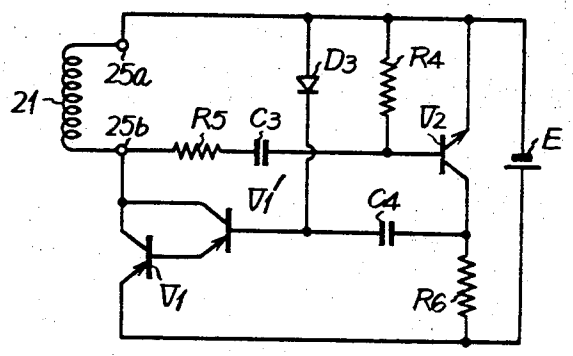


Fig. 12



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United States Patent Office 3,407,344
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3,407,344

ELECTRONIC TIMEKEEPER

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Claims priority, application Japan, Sept. 26, 1964, 39/55,173
3 Claims. (Cl. 318—130)

ABSTRACT OF THE DISCLOSURE

This invention relates to an electronic timekeeper wherein a balance wheel has permanent magnets mounted thereon and a free-running multivibrator associated therewith. A load for the multivibrator is provided by a coil which drives the balance wheel by a mutual action of the flux through the coil and the permanent magnets so that the oscillation period of the multivibrator is controlled by the inherent vibration period of the balance wheel and synchronized therewith.

This invention relates to an electronic timekeeper such as an electronic watch or clock. More particularly, this invention is directed to the provision of an electronic timekeeper which comprises a balance wheel having mounted thereon permanent magnets and a free-running multivibrator having as a load a magnetic coil for driving the balance wheel and in which the balance wheel is driven by a force based upon the mutual action of the flux produced by the impulse fed to the magnetic coil of the free-running multivibrator and that of the permanent magnets mounted on the balance wheel in a manner so that the oscillation period of the free-running multivibrator is controlled by the mechanical inherent vibration period of the balance wheel and synchronized therewith.

It is one object of this invention to provide an electronic timekeeper having no electrical contacts.

It is another object of this invention to provide an electronic timekeeper which is low in power consumption.

It is another object of this invention to provide an electronic timekeeper which is easy to mass-produce at low cost.

It is another object of this invention to provide a self-start electronic timekeeper.

It is still another object of this invention to provide a highly precision electronic timekeeper which withstands vibrations or shocks applied thereto from the outside.

Other objects, features and advantages of this invention will appear from the following description taken in conjunction with the accompanying drawings, in which:

FIGURE 1 is a side view of an electronic timekeeper of this invention schematically illustrating an example thereof and an electrical system of a free-running multivibrator for use with the electronic timekeeper;

FIGURE 2 is a schematic plan view illustrating the relationship between the mechanical part including a balance wheel and a driving coil in the electronic timekeeper illustrated in FIGURE 1;

FIGURES 3A to 3E, inclusive, are curves for explaining the operation of the electronic timekeeper illustrated in FIGURE 1;

FIGURE 4 illustrates curves for explaining the build-up condition of a pulse induced in the driving coil by the magnets of the balance wheel at the start thereof;

FIGURE 5 is a circuit diagram illustrating another example of the multivibrator which is suitable for reducing the build-up time of the balance wheel;

FIGURE 6 is a circuit diagram illustrating another example of the multivibrator by which the width and amplitude of a pulse produced in the driving coil is automatically changed respectively at the start and during the steady-state operation;

FIGURE 7 is a modified form of the circuit illustrated in FIGURE 6;

FIGURES 8 and 9 are further modified forms of the circuit illustrated in FIGURE 6;

FIGURE 10 is a modification of the circuit illustrated in FIGURE 9;

FIGURE 11 is a circuit diagram in which one of the diodes in the circuit illustrated in FIGURE 6 has been removed; and

FIGURE 12 is a circuit diagram illustrating a still further example of the multivibrator usable in this invention.

In FIGURES 1 and 2 reference numeral **1** indicates a balance wheel and **2** its rotary shaft. The rotary shaft **2** is supported between fixed base plates **3** and **4**, as illustrated in FIGURE 1. Reference numerals **5***a* and **5***b* identify bearing portions for supporting the rotary shaft **2**. Reference numeral **6** indicates a spiral hair spring wound about the rotary shaft **2**, the inner end of the spring **6** being fixed to the shaft **2** and the outer end being fixed to an arm attached to the fixed base plate **3**. Reference numeral **8** identifies a driving screw member mounted on the rotary shaft **2**, and **10** designates a wheel mounted on a stationary axis *ax* and driven by the driving screw member **8**. The wheel **10** is interlocked with the hands of the timekeeper through a gear mechanism including a gear diagrammatically illustrated for the purpose of exemplification. The driving screw member **8** is provided with a helical inclined plane **8***a* and adapted so that radial fingers **10***a* of the wheel **10** are sequentially pushed up by the inclined plane **8***a* in response to the rotation of the rotary shaft **2** to thereby rotate the wheel **10** about the axis *ax*.

On the rotary shaft **2** there is mounted a sleeve **11** made of a magnetic material in a manner to rotate together with the rotary shaft **2**. Both ends of the sleeve **11** have mounted thereon discs **13** and **14**, each consisting of semicircular plates respectively formed of magnetic and non-magnetic materials. On the opposing faces of the discs **13** and **14** there are mounted permanent magnets **15** and **16** of, for example, rectangular parallelepiped shape, spaced apart a distance as identified at **17**. These magnets **15** and **16** are placed along the reference line O—O of the rest position of the rotary shaft **2**, as illustrated in FIGURE 2. The width and length of each magnet in the rotary and radial directions of the disc are selected approximately the same K, as will be described later. The opposing faces of the magnets **15** and **16** are, of course, flat and constitute magnetic poles N and S respectively.

On the opposing faces of the discs **13** and **14** there are disposed balance weights **19** and **20** spaced a distance, as identified at **18**, at the position diametrically opposite to the magnets **15** and **16**. Furthermore, a driving coil **21** is disposed between the magnets **15** and **16** on the reference line O—O. The driving coil **21** is wound in a manner to form therein a central aperture **22** of an equilateral triangle in cross section and placed so that the bisector of the triangle may lie exactly on the reference line O—O and that the peak may stay on the side of the rotary shaft **2**. In this case the length of the base side of the aperture **22** and the width of winding of the coil are also selected approximately K which is the width of the magnets **15** and **16**. In addition, the both faces of the coil **21** confronting the magnets **15** and **16** are formed flat. Reference numeral **23** identifies a support member of the driving coil **21**.

When the rotary shaft **2** is at a standstill, the magnets **15** and **16** cover the central aperture **22**. The driving coil **21** is connected to the output terminals **25***a* and **25***b* of a free-running multivibrator **24**.

The multivibrator **24** consists of, for example, PNP-type transistors V_1 and V_2 of the same conductivity type, as illustrated in FIGURE 1. That is, the emitters of the transistors V_1 and V_2 are connected to the plus side of a DC power source E. The collector of the transistor V_1 is connected to the minus side of the DC power source E through the output terminal **25***b*, the driving coil **21** and the other output terminal **25***a*, while the collector of the transistor V_2 is similarly connected to the minus side of the DC power source E through a resistor R_3. The base of the transistor V_1 is also connected to the minus side of the DC power source E through a resistor R_2 on the one hand and through a series circuit of a capacitor C_2 and a resistor R_3 which is parallel to the resistor R_2 on the other hand, while the base of the transistor V_2 is likewise connected to the minus side of the DC power source E through a resistor R_1 on the one hand and through the capacitor C_1 and the driving coil **21** on the other hand. The capacitor C_1, the resistor R_1 and the capacitor C_2, the resistor R_2 respectively constitute elements which determine the time constants T_1 and T_2 for the conduction and non-conduction of the oscillation of the multivibrator **24**. In this case, the time constant T_1 determined by the capacitor C_1 and the resistor R_1 and the time constant T_2 by the capacitor C_2 and the resistor R_2 are selected such that $T_1 \ll T_2$. Meanwhile, the oscillation period T_f of the multivibrator **24** equals the sum of the time constants T_1 and T_2 but the oscillation period T_f is selected equal to or slightly greater than one half of the vibration period T_m under the steady-state operation of the balance wheel **1**.

In FIGURE 3A there is illustrated the wave form **25** of the vibration of the balance wheel **1** with respect to the reference line O—O. In FIGURE 3B there is illustrated the oscillating wave form of the output of the multivibrator **24** which is fed to the magnetic coil **21** during free running of the multivibrator **24**, namely reference numeral **26** indicating the oscillating wave form produced while the flux of the magnetic coil **21** and that of the magnets **15** and **16** do not cross each other. In this case the reference zero voltage is the potential of the minus side of the power source E. Under such conditions, the multivibrator **24** starts to oscillate and the output is delivered to the magnetic coil **21**, so that the upper and lower ends of the magnetic coil **21** are polarized N and S respectively, rotating the discs **13** and **14** and consequently the rotary shaft **2** a little to the left, for example, from the rest position due to the repulsion between the fluxes of the magnetic coil **21** and the magnets **15** and **16**. Subsequent to the rotation due to the repulsion, the discs **13** and **14** are then pulled backward to the right by the reaction of the spiral hair spring **6**, the center of the magnets **15** and **16** travelling past the reference line O—O to the right of the magnetic coil **21**. Following this, the discs **13** and **14** are then rotated to the left again in the same manner. In this case, since the pulse is fed to the magnetic coil **21** whenever the magnets **15** and **16** run past the reference line O—O to the right and left, the discs **13** and **14** are energized each time to move to the right and left past the reference line O—O at angles θ and θ' thereto respectively.

Now, description will hereinbelow be made in connection with the control of the operation of the multivibrator **24** by the constant-speed vibration or the isochronism of the balance wheel **1**. When the balance wheel **1** vibrates, pulses **27** opposite in sense, as illustrated in FIGURE 3C, are induced in the driving coil **21** by the fluxes of the magnets **15** and **16** and the polarity of the pulses **27** is reversed when the magnets **15** and **16** pass the reference line O—O. With the lapse of time, the induced pulse **27** becomes gradually larger as illustrated by the curves *a* to *c* in FIGURE 4, and the transistor V_2 of the multivibrator **24** is triggered at a certain level L through the capacitor C_1. In this manner the multivibrator **24** is controlled by the isochronism of the balance wheel **1** and synchronized therewith. As is apparent from the foregoing, the multivibrator **24** continues to oscillate while being pulled in by the induced pulse **27** based upon the isochronism of the balance wheel **1** and in turn such an oscillator drives the balance wheel **1**. By carrying out such an operation repeatedly, the balance wheel is kept in isochronal operation, while the magnetic coil **21** is supplied with output pulses **28** each synchronized with the inherent vibration period T_m of the balance wheel **1** under the steady state thereof, as illustrated in FIGURE 3D, thereby maintaining the driving of the balance wheel **1**.

An example of the numerical values of this invention is as follows:

K: 5 mm.
Width of the magnets **15** and **16**: 2 mm.
T_m: 500 m. sec.
V_1 and V_2: 2SB38P
C_1: 0.3 μf.
C_2: 30 μf.
R_1: 100KΩ
R_2: 750 KΩ
E: 1.5 v.
Coil **21**: resistance 300Ω, 1200 turns, diameter of wire 0.04 mm., thickness of the entire coil in the axial direction of winding 2 mm.

The present invention has been described in connection with the case where the width or the time constant T_1 of the pulse **28** applied to the driving coil **21** is constant. However, it is preferred to slightly increase the width of the pulse **28** from the starting point thereof in order to reduce the build-up time of the balance wheel **1** and to ensure the starting thereof.

FIGURE 5 illustrates a multivibrator circuit for accomplishing this, parts similar to those in FIGURE 1 being identified by the same reference numerals, but no further description will be made thereon for the sake or simplicity. As illustrated in the figure, each one end of resistors R_1 and R_2 is connected to the minus side of the DC power source E through the normally closed contact S_1 of a push-button switch SW and each one end of resistors R_1' and R_2' is connected to the base of each of the transistors V_1 and V_2, while the other ends are connected together to the minus side of the power source E through the normally open contact S_2 of the switch SW. In this case the value of the resistor R_1 is selected smaller than that of the resistor R_1'.

With such an arrangement, when the contact S_2 is closed by the movable contact S_0 of the switch SW, the width T_1' of the pulse **28'** applied to the magnetic coil **21** becomes wider than that T_1 of the pulse **28** shown in FIGURE 3B, as illustrated in FIGURE 3E. Therefore, the build-up time of the balance wheel **1** can be shortened by turning the switch SW to the contact S_2 for an extremely short period of time when starting. Meanwhile, since the pulse width during steady-state operation is narrower than that required at the start, the power consumption from the DC power source E can be reduced. Furthermore, the driving coil **21** is energized by the pulse of narrow width, so that the accuracy of the isochronism of the balance wheel **1** can be enhanced further.

The present invention has been described above in connection with the case where the power consumption is reduced by narrowing the pulse width at the start. It is of course possible, however, that the pulse width and amplitude can automatically be increased at the start and decreased during steady-state operation. FIGURE 6 illustrates a circuit for this purpose, in which a diode D_1 is connected in series to the resistor R_1 in a manner so that the plate of the diode D_1 is connected to the minus side of the DC power source E and the cathode is connected through a diode D_2 to the collector of the transistor V_1.

With the use of such a circuit, the amplitude of the

vibration of the magnets **15** and **16** is small, and hence the amplitude of the pulse induced in the driving coil **21** is also small. The internal resistance of the diodes D_1 and D_2 is great because a backward bias has been applied to them, and consequently the time constant of the multivibrator **24** is great, including the sum of the resistance of the resistor R_1 and the internal resistance of the diodes and that of the capacitor C_1. As a result the width of the pulse fed to the magnetic coil **21** is great, as illustrated in FIGURE 3E. As will be seen from the voltage-current characteristic of the diode, the internal resistance of the diodes gradually decreases with an increase in the amplitude of the pulse **27** induced in the driving coil **21**, reducing the time constant and the pulse width. On the other hand, the energy stored in the capacitor C_2 decreases with a decrease in the pulse width and the amplitude of the pulse delivered to the driving coil **21** also decreases. Accordingly, only at the start of the operation the driving coil **21** is supplied with a pulse **28'** having necessary width and amplitude and thereafter the balance wheel **1** is usually driven by a pulse **28** of smaller width and amplitude, so that power consumption can be reduced. In addition, precision can be enhanced due to the narrow width of the driving pulse.

The circuit illustrated in FIGURE 7 is exactly the same as that in FIGURE 6 except that the internal resistance of the transistor V_1 performs the function of the resistor R_2 which has been omitted.

FIGURE 8 illustrates a modified form of the circuit in which the diode D_1 shown in FIGURE 7 has been left out.

FIGURE 9 illustrates a modification of the circuit shown in FIGURE 6 in which the power source of the resistor R_2 is cut off and the resistor R_2 is connected in series with a diode D_3, the cathode of which is connected to the collector of the transistor V_2.

FIGURE 10 illustrates a circuit in which the diode D_1 in FIGURE 9 has been removed.

FIGURE 11 illustrates a circuit in which the diode D_1 in FIGURE 6 has been left out.

The operation of the circuit shown in FIGURES 5 to 11, inclusive, will be apparent from the foregoing description taken in connection with FIGURE 1.

FIGURE 12 is a still further modified form of the multivibrators according to the present invention, in which the multivibrator consists of transistors V_1 and V_1' of the same conductivity type and another transistor V_2 of different conductivity type. That is, the base of the transistor V_1 is connected to the emitter of the transistor V_1' and the collectors of the two transistors are connected together, the emitter of the transistor V_1 being connected to the plus side of the DC power source E and the emitter of the transistor V_2 being connected to the minus side of the power source E. The base of the transistor V_2 is connected through a resistor R_4 to the plus side of the power source E. The collectors of the transistors V_1 and V_1' are connected to the base of the transistor V_2 through a series circuit of a resistor R_5 and a capacitor C_3 and the collector of the transistor V_2 is also connected through a capacitor C_4 to the base of the transistor V_1' and to the plus side of the power source E through a resistor **6**, and in addition, the bases of transistors V_1' and V_2 are connected to the minus side of the power source E respectively through a diode D_3 and resistor R_4.

The numerical embodiment illustrated in FIGURE 12 is as follows:

V_1 and V_1': 2SB38P
V_2: 2SD66
Diode D_3: SD102
C_3: 1 μf.
R_4: 300KΩ
R_5: 90KΩ
R_6: 14.5 KΩ
Coil: impedance 300Ω, 1200 turns, diameter of wire 0.04 mm., width of the axial direction 2 mm.

While several embodiments of this invention have been described in connection with the case where the balance wheel is employed it is to be understood that the present invention is applicable to electronic clocks employing a pendulum in place of the balance wheel.

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of this inveniton.

What I claim is:

1. An electronic timekeeper comprising a balance wheel mounted on a rotary shaft, said balance wheel consisting of a sleeve of a magnetic material surrounding the rotary shaft and a pair of opposing discs contiguous to the sleeve, one portion of each disc being magnetic, a pair of permanent magnets mounted on the magnetic portion of each disc with a predetermined distance therebetween, the opposing faces of said pair of permanent magnets being opposite in polarity, a flat driving coil disposed between the pair of discs in the rotary angular range of the pair of permanent magnets, said driving coil being wound in a manner to form therein a central aperture of an equilateral triangle in cross-section and so placed that the peak of said triangle stays on the side of said rotary shaft, the width of the winding of said driving coil around said aperture being selected to be substantially equal to the length of the base of said triangle aperture and the width of said magnets in the direction of the circumference of said disc, and a free-running multivibrator for energizing said driving coil, the oscillation period of said free-running multivibrator being selected equal to or greater than one-half of the vibration period of the balance wheel, the output of the free-running multivibrator being delivered to the driving coil in a manner so that when a driving pulse is applied to the driving coil a magnetic field of the same polarity as the pair of permanent magnets may be established in the faces of the driving coil confronting the pair of permanent magnets, the oscillation period of the free-running multivibrator being controlled by a pulse induced in the driving coil each time the pair of permanent magnets pass the driving coil during the operation of the balance wheel, and the output of the free-running multivibrator produced thereby being applied to the driving coil, thereby repelling the pair of permanent magnets immediately after they have just passed the center of the driving coil.

2. An electronic timekeeper as claimed in claim **1**, wherein the free-running multivibrator is provided with means for selecting the time constant in a manner so that the width of the output pulse of the free-running multivibrator at the start thereof may be greater than that of the pulse during the steady-state operation.

3. An electronic timekeeper as claimed in claim **1**, wherein the free-running multivibrator is provided with means for automatically selecting the time constant in a manner so that the width of the output pulse of the free-running multivibrator at the start thereof may be greater than that of the pulse during the steady-state opreation.

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