United States Patent

Usui

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[54] **ELECTROMAGNETIC DRIVING APPARATUS**

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[52] **U.S. Cl.** .....**58/28 A**, 318/130

[51] **Int. Cl.** **G04c 3/04**

[58] **Field of Search** ....58/23 V, 28 R, 28 A; 318/130

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[57] **ABSTRACT**

An electromagnetic driving apparatus for both driving at a uniform oscillation a balance wheel in a timepiece as well as detection and having a driving circuit which provides a series of pulses to an electromagnetic coil supported between two permanent magnets having opposite polarity and mounted on the balance wheel. The coil, due to the electromagnetic effect imposed upon the coil by the periodically passing magnets, causes the production of a series of resultant positive pulses for driving the balance wheel. The balance wheel is maintained in a natural period of simple harmonic motion by the time period of the resultant pulses imposed upon the coil, this time period determined by a pulse timing circuit in the driving circuit.

6 Claims, 5 Drawing Figures

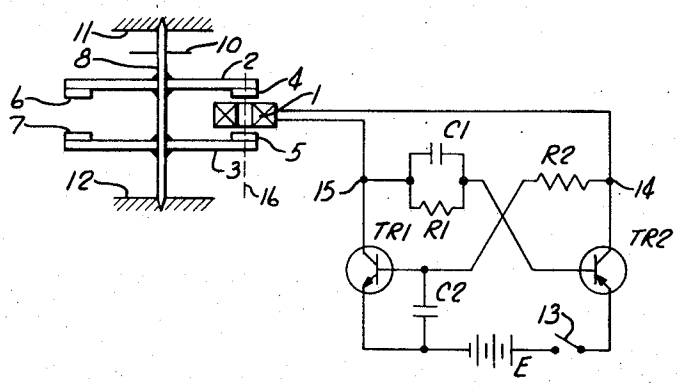

Fig. 1

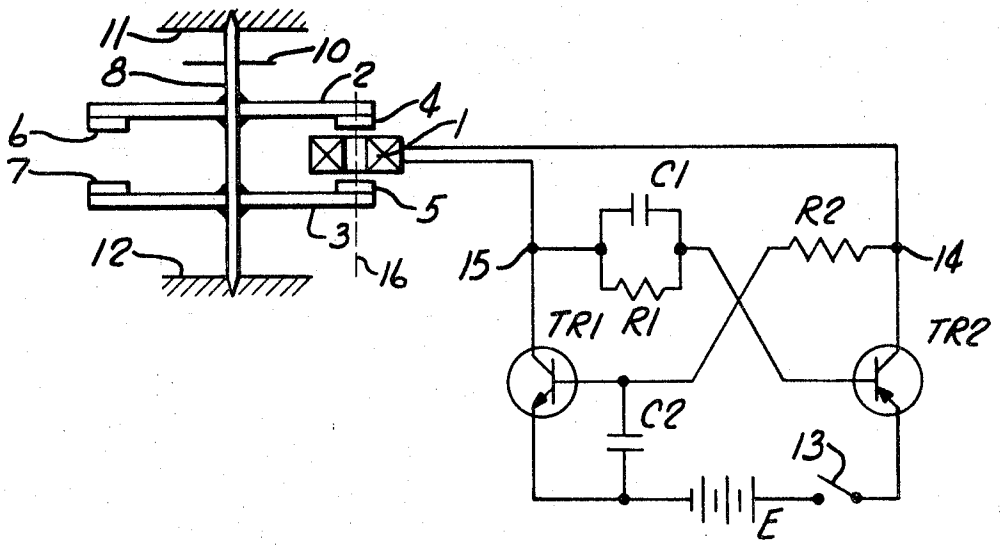

Fig. 2a

Fig. 2b

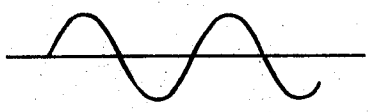

Fig. 2c

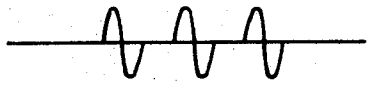

Fig. 2d

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ELECTROMAGNETIC DRIVING APPARATUS

BACKGROUND OF THE INVENTION

The present invention relates to an electromagnetic driving apparatus particularly adapted for a timepiece for driving the same by means of a combination transistor circuit and permanent magnet.

Heretofore, in electromagnetic driving apparatus for timepieces, it has been a common practice to provide two coils in the driving mechanism, one a driving coil and the other a detecting coil. However, the electromagnetic driving apparatus of the present invention consists of a single coil for both driving the timepiece as well as for the purposes of detection.

SUMMARY OF THE INVENTION

The principle object of the present invention is to provide an electromagnetic driving apparatus which utilizes a single coil for both driving as well as for detection, which is self-excited, and which is simple in electric circuit construction.

Another provision of this invention is an electromagnetic driving apparatus comprising a circuit employing an NPN transistor and a PNP transistor, the collectors of the transistors being connected to each other through a single coil for both driving and detecting. The base of the NPN transistor is connected to the collector of the PNP transistor through a resistor, and the base of the PNP transistor is connected to the collector of the NPN transistor through a parallel circuit consisting of a capacitor and a resistor. The emitters of the transistors are connected across a power source.

Other objects and advantages appear in the following description and claims.

The accompanying drawings show, for the purpose of exemplification without limiting the invention or the claims thereto, certain practical embodiments illustrating the principles of this invention wherein:

FIG. 1 is a circuit diagram of the electromagnetic driving apparatus comprising this invention.

FIG. 2*a* is a current waveform in the coil of the electromagnetic driving apparatus when in self-excited oscillation.

FIG. 2*b* is an illustrative waveform of the sinusoidal motion of the balance wheels of a timepiece.

FIG. 2*c* is a voltage waveform of the electromotive force generated in the coil of the electromagnetic driving apparatus.

FIG. 2*d* is the resultant current waveform applied to the coil of the electromagnetic driving apparatus.

Referring now to FIG. 1, the transistor TR1 is of the NPN type while transistor TR2 is of the PNP type. The emitters of transistors TR1 and TR2 are connected respectively to each side of the power supply E. Switch 13 is provided in series with the power supply E for selectively placing the circuit in and out of operation.

The base of transistor TR1 is connected through biasing resistor R2 to the collector of transistor TR2 by means of line 14, and also through capacitor C2 to the same terminal of the power supply E that the emitter of the transistor TR1 is connected. Line 14 is also connected to one side of coil 1.

The base of transistor TR2 is connected to the parallel circuit comprising capacitor C1 and resistor R1. The other side of this parallel circuit is connected though line 15 to the other side of coil 1 and also to the collector of transistor TR1.

The balance wheel consists of the wheel members 2 and 3 each secured to the balance wheel shaft 8. The balance wheel shaft 8 is pivotally supported as shown in the supporting base structure designated at 11 and 12. The balance wheel members 2 and 3 are secured to the shaft 8 an equal distance from the supporting base structure 11 and 12 and in parallel aligned position.

The magnets 4 and 5 are respectively supported on one end of each of the balance wheel members 2 and 3 in opposed relation as shown in FIG. 1. The opposing surfaces of the magnets 4 and 5 are of opposite polarities to each other so that a natural magnetic flux exists between the magnets thereby attracting one another. Diametrically opposite each of the magnets 4 and 5 on the balance wheel members 2 and 3 are the balancers 6 and 7, respectively, to act as counterweights for the diametrically opposite magnets on each of the wheel members 2 and 3.

Hairspring 10 is provided with one end secured to the shaft 8, as shown, and its other end secured to a fixed structure (not shown).

From the foregoing description, it can be seen that the coil 1 is used both to drive the balance wheel as well as to act as a means of detection, as it is between and adjacent each of the magnets 4 and 5.

Specific reference will now be made to the operation of the circuit which drives the balance wheel members 2 and 3 through their respective magnets 4 and 5. When the switch 13 is closed, the power source E supplies current to the emitter of the transistor TR2, through the collector of the same and thence to the coil 1 and to the transistor TR1, and thence flows from the emitter of the transistor TR1 back to the power source E. The capacitor C1 is charged by the base current of the transistor TR2.

When the condenser C1 has been sufficiently charged, the base of the transistor TR2 becomes more positive, and thus transistor TR2 is turned off. As a result, capacitor C1 discharges through the resistor R1, and upon completion of this discharge the transistor TR2 turns on again. The above-mentioned operation is then repeated.

As a result, the transistor circuit illustrated in FIG. 1 goes into self-excited oscillation. The current waveform in the coil 1 at this time is illustrated in FIG. 2*a*.

On the other hand, since the coil 1 is located between the magnets 4 and 5 of the balance wheels 2 and 3, respectively, when one oscillation pulse passes through the coil 1, the magnets 4 and 5 are subjected to a repulsive force from the coil 1, resulting in a rotary motion imparted to the balance wheel members 2 and 3 around the axis of the balance shaft 8.

The energy of this rotational motion is stored in the hairspring 10. The balance wheels 2 and 3 are then caused to rotate in an opposite direction to that first mentioned above, caused by the repulsive force due to the restoring force of the hairspring 10. Thus, the magnets 4 and 5 pass adjacent to the coil 1, and thereby generate an electromotive force in the coil 1. The voltage waveform of this generated voltage is shown in FIG. 2*c*. The motion of the balance wheels is oscillatory, first in one direction and then another returning to the position shown in FIG. 1 by means of the restoring force in the hairspring 10.

Although the transistor TR1 is conducting during the positive portions of the alternative voltage pulses, the base of the transistor TR1 becomes positive during the negative portions of the alternative voltage and its base becomes negative so that transistor TR1 turns off resulting in no current flow in the circuit. In other words, the transistor TR1 achieves a phase transition effect.

More particularly, a current only flows through the coil 1 in a direction from the collector of the transistor TR2 to the collector of the transistor TR1. This current is illustrated in FIG. 2*d*.

FIG. 2*b* is an illustration of the motion of the balance wheels which is a sinusoidal motion. If the time constant $t = (C1)(R1)$ of the capacitor C1 and the resistor R1 is determined so that the driving circuit may generate a pulse each time when the balance wheel members pass through the position illustrated in FIG. 1, to wit, between the magnets 4 and 5, then the alternating voltage pulses generated by the magnets and illustrated in FIG. 2*c* are fed to the coil 1 as an input at the same time the oscillation pulses illustrated in FIG. 2*a* of the driving circuit are imposed upon coil 1. These alternating voltage pulses being subjected to a phase transition through the transistor TR1, are converted into the waveform as illustrated in FIG. 2*d*, which is applied to the coil 1 together with the oscillation pulse current to provide the necessary driving force to the balance wheel members 2 and 3.

In this manner, the motion of the balance wheel is amplified and the balance wheel performs a stable rotary reciprocating motion at a balancing point where the elastic force of the hairspring 10 and the driving force imposed by the coil 1 balance with each other.

In this connection, the circuit shown can operate as a two terminal network. Also, there occurs very little ineffective current, so that the circuit is simple in structure with little power consumption, rendering it very favorable for use in an electric timepiece.

In FIG. 1, the capacitor C2 is provided for the purpose of filtering out high frequency components.

In addition, while a PNP transistor is used for oscillation and an NPN transistor is used for phase transition in the above-mentioned embodiment, it is a matter of common knowledge that a similar operation could be achieved even if each of these transistors were of the opposite type. In such a situation, naturally, the power source E should be connected to reverse the polarity so that the current flowing through the coil 1 is reversed.

It should be noted that while the above description pertains to the development of a repulsive force exerted between the coil 1 and the magnets 4 and 5, it is also possible to cause the oscillatory sinusoidal movement of the balance wheel by means of employing an attracting force which may be exerted to attract the balance wheel members 2 and 3 prior to their passing adjacent to the coil 1.

The starting movement of the balance wheel may be facilitated by the centers of the magnets 4 and 5 relative to the center of the coil 1. Thus, for example, when the balance wheel is in the position shown in FIG. 1, the magnets 4 and 5 may be positioned on the edge of each of the balance wheel members in such a manner that magnet 4, as viewed in FIG. 1, would be above the center line 16 of coil 1 whereas magnet 5 would be positioned slightly below the center line 16 of coil 1.

It should be noted that the time period of the oscillatory pulses of the driving circuit illustrated in FIG. 2*a* are unstable. However, since the time period of pulses developed by the driving circuit is controlled by the voltage pulses induced in the coil 1 by the action of the magnets 4 and 5, the resultant time period of the driving circuit is stabilized. Also, even if the oscillation period of the driving circuit and the period of the simple harmonic motion of the balance wheels determined by the hairspring 10 are somewhat different from each other, a stable simple harmonic motion of the balance wheels can be provided for by adjustment to the driving circuit as, for example, changing the RC time constant of C1 and R1.

Thus, what is provided is an electromagnetic driving apparatus which can be self-excited by means of only a single coil.

Furthermore, the electromagnetic driving apparatus achieves a stable operation, which is simple in circuit construction and has little power consumption.

Various modifications and departures, such as the type of power source or semiconductor devices to provide the oscillation pulse, are readily contemplated and knowledgeable to those skilled in this art and may obviously be resorted to without departing from the spirit and scope of the invention as hereinafter defined by the claims.

I claim:

1. An electromagnetic driving apparatus for driving at a uniform sinusoidal oscillation a balance wheel in a timepiece comprising oppositely opposed magnets mounted on said balance wheel, said magnets having opposite polarity, an electromagnetic coil supported to be positioned between said oppositely opposed magnets, said magnets passing adjacent to said coil when said balance wheel is in sinusoidal oscillation, pulse circuit means to drive said balance wheel through said coil and comprising two transistors of opposite conductive type relative to each other having their collectors connected to each other through said coil, the base of the first transistor connected through biasing resistance to the collector of the second transistor and the base of the second transistor connected through a pulse timing circuit to the collector of the first transistor, and a power source connected between the emitters of said two transistors.

2. The electromagnetic driving apparatus of claim 1 characterized in that said magnets are mounted on said balance wheel in oppositely opposed relation in a manner to be transversely aligned relative to each other.

3. The electromagnetic driving apparatus of claim 1 characterized in that said balance wheel consists of two wheel members secured in spaced distance to a shaft mounted for sinusoidal oscillatory movement, said magnets each mounted adjacent to the edge of said wheel members in facing relationship, the first of said magnets having a polarity opposite to the second of said magnets, a counter weight secured to each of said wheel members diametrically opposite to each of said magnets to balance said wheel members, said coil mounted between said wheel members to interrupt the magnetic lines of force when said balance wheel is in oscillatory operation.

4. The electromagnetic driving apparatus of claim 3 characterized in that said pulse timing circuit is a re-

sistor and a capacitor connected in parallel, the time constant of which is determinative of the rate of pulses supplied to said coil.

5. The electromagnetic driving apparatus of claim 1 characterized in that said pulse timing circuit is a resistor and capacitor connected in parallel, the time constant of which is determinative of the rate of pulses supplied to said coil.

6. An electromagnetic driving apparatus for driving at a uniform sinusoidal oscillation a balance wheel in a timepiece with the minimum of power consumption comprising a pair of oppositely opposed permanent magnets mounted on said balance wheel in spaced relation, the opposing faces of said pair of permanent magnets being opposite in polarity, an electromagnetic coil disposed between said oppositely opposed magnets, said magnets passing adjacent to said coil when said balance wheel is in sinusoidal oscillation inducing an electromotive force in said coil, pulse circuit means to drive and maintain said balance wheel in its natural vibration period comprising two transistors of opposite conductive type relative to each other and having their collectors connected to each other through said coil, the base of the first transistor connected through a biasing resistor to the collector of the second transistor and the base of the second transistor connected through a timing circuit consisting of a charging resistor and charging capacitor connected in parallel to the collector of the first transistor, the RC time constant of said timing circuit selected to adjust the time period of the resultant pulses produced by said pulse circuit means to stabilize the maintenance of the oscillatory motion of said balance wheel, a power source connected between the emitters of said two transistors, the power consumption for said circuit means through said power source limited to a portion of each cycle of the oscillatory motion of said balance wheel for charging said charging capacitor.

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