

[54] TIMEKEEPING DEVICES

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[51] Int. Cl.G04c 3/04, H03b 3/02

[58] Field of Search58/23, 23 A, 28, 28 A, 28 B;
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[56] References Cited

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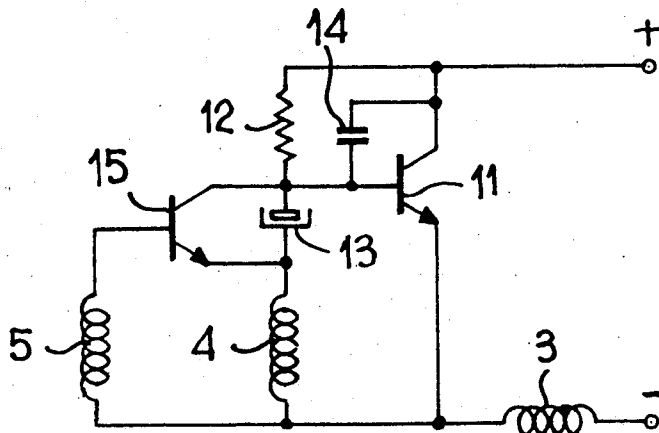
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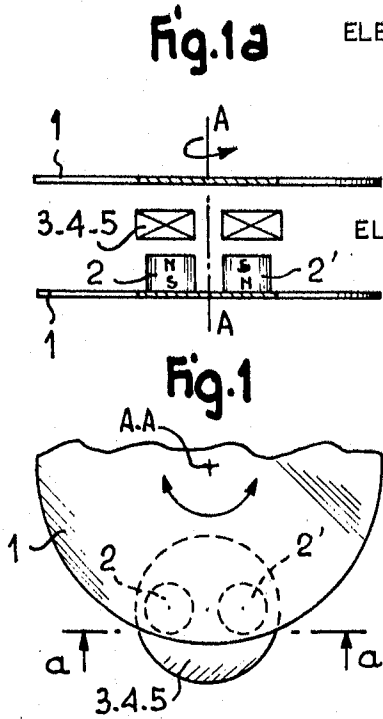
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[57] ABSTRACT

A timekeeping device is provided with a mechanical oscillator electronically sustained without contact. A balance-wheel bearing permanent magnets induces electromotive force in two coils placed at the point of static equilibrium of the wheel. The electromotive forces are used in an amplifier transistor to supply through a third coil coaxial with the two previous ones a sustaining power, and are further used to control a regulator transistor which acts upon the point of operation of the amplifier transistor in such a way as to vary the power supplied in inverse ratio to the amplitude of the oscillations.

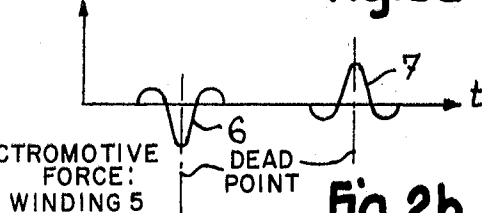
11 Claims, 10 Drawing Figures





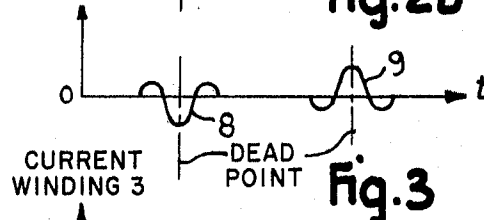
ELECTROMOTIVE FORCE:
WINDING 4

Fig. 2a



ELECTROMOTIVE FORCE:
WINDING 5

Fig. 2b



CURRENT
WINDING 3

Fig. 3

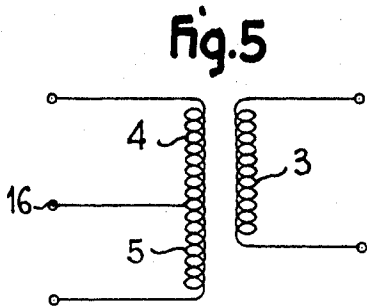
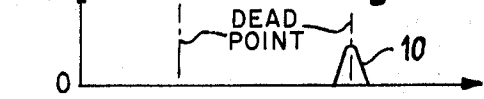


Fig. 4

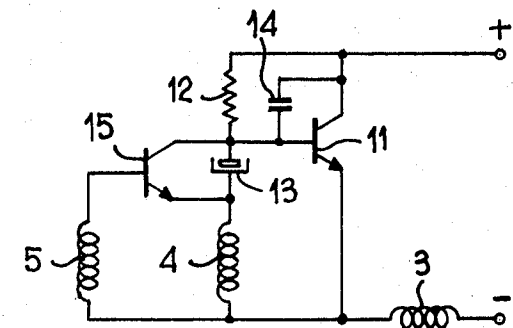


Fig. 6

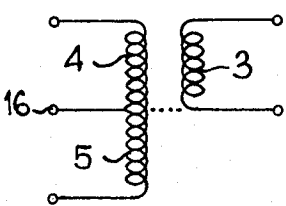


Fig. 7

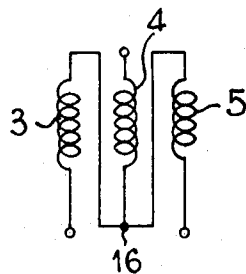
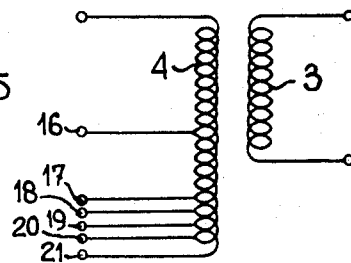


Fig. 8



TIMEKEEPING DEVICES

The present invention relates to timing devices for watches, clocks, and the like of the type comprising a balance-wheel, pendulum, or the like, the movement of which is maintained electronically without physical contact.

The stability of operation of such systems is not always satisfactory, as they are sensitive to variations of the ambient temperature and of the supply voltage.

An object of the invention is to provide regulation of the power supplied electronically to maintain oscillation at a nearly constant amplitude.

According to the invention a timing device comprises an oscillatory member, magnetic means on the member, stationary control, driving, and regulating, windings co-operating with the magnetic means, a main transistor controlling energization of the driving winding from a supply, the control winding being connected to control operation of the main transistor, and a bias circuit for the main transistor including a second transistor and the regulating winding for varying the bias of the main transistor in dependence on a characteristic of the oscillations of the member.

The control and regulating windings may be connected in series across two electrodes of the second transistor; a condenser connected across the second transistor may be included in the bias-circuit to establish a means bias on the main transistor which depends upon the voltage generated in the regulating winding, and hence upon the amplitude of oscillation.

The invention may be carried into practice in various ways and certain embodiments will now be described by way of example with reference to the accompanying drawings of which:

FIG. 1 is a partial plan view of a balance wheel embodying the invention and for use in controlling the operation of a clock in a motor-car or a watch;

FIG. 1A is a section on the line $a-a$ in FIG. 1;

FIGS. 2A and 2B are graphs showing displayed against time voltages induced in two windings on the balance wheel of FIG. 1 during an oscillation;

FIG. 3 is a similar graph showing the current generated in a third winding on the balance wheel of FIG. 1;

FIG. 4 is a circuit diagram showing how the windings in FIG. 1 are electrically connected; and

FIGS. 5, 6, 7 and 8 are diagrams of different arrangements of the windings in the balance wheel of FIG. 1.

The balance wheel consists of two spaced plates 1 arranged to oscillate about an axis A against restraint provided by a conventional hair spring (not shown). The lower plate 1 carries two permanent magnets 2 and 2' which have opposite poles against the plate 1. The magnets co-operate during oscillations with an assembly of driving, control, and regulating, windings 3, 4, and 5, which are co-axially arranged about an axis which is mid-way between the permanent magnets 2 and 2' in a dead-center position of the balance wheel, which is the position in which the hair spring is not deflected.

During an oscillation, first a voltage is generated in the windings 4 and 5 in one sense as one of the magnets passes one side of the windings, and then voltages are generated in the windings in the other sense due to both of the magnets 2 and 2' passing respective sides, and then the second magnet generates a voltage in the windings 4 and 5 in the first sense so that during each oscillation there are two voltages generated in each of the windings 4 and 5 as indicated in FIGS. 2A and 2B. Each voltage is symmetrical about a position representing the dead-center position, and the voltages are of opposite senses in accordance with the direction in which the magnetic lines of force cross the turns of the windings.

The windings are connected in circuit as indicated in FIG. 4.

The driven winding 3 is connected in series with a direct voltage provided by a battery through the emitter and collector of a first amplifying transistor 11 so as to be energized from the supply whenever the transistor is switched on.

The transistor base has a biasing circuit including a resistor 12, a condenser 13, and the control winding 4, connected

across its collector and emitter with the base connected to the junction of the resistor 12 and the condenser 13. The transistor 11 is normally biased off but can be switched on due to voltages of appropriate amplitude generated in the control winding 4, and in general the bias is set so that the transistor 11 is switched on and the driving winding 3 is energized only during the large positive peaks of the voltages indicated at 7 and 9 in FIGS. 2A and 2B. A condenser 14 connected across the collector and base of the transistor 11 prevents the circuit from being self-oscillatory in spite of the high coupling between the windings 3 and 4.

As with a Frony oscillator, the voltage on the base of the transistor 11 at which it becomes conducting is determined by the voltage at the terminal of the condenser 13.

The invention provides a system for automatically regulating the intervals during which current is supplied to the driving winding 3, and thus the driving power applied to maintain the wheel 1 in oscillation in accordance with the amplitude of the oscillations to tend to keep this amplitude constant.

This regulation is achieved by means of a second transistor 15 with its collector and emitter connected across the condenser 13 to act with the resistor 12 and the condenser 13 to rectify and smooth signals applied between its base and its emitter. These signals are derived from the windings 4 and 5 which are connected in series across the emitter and base, their common point being also connected to the emitter of the transistor.

The operation of the circuit is as follows. The biasing circuit for the transistor 11 consisting of the resistance 12 and the condenser 13 provides a bias as indicated by the X-axis in FIG. 2 so that the part of the wave form at 7 triggers the transistor 11 on and causes current flow in the driving winding 3 as indicated in FIG. 3 at 10 which represents an operation when the voltage at the terminal of the condenser 13 is equal to the base/emitter threshold voltage of the transistor 11. It is clear from FIGS. 2 and 3 that adjustment of the mean voltage across the condenser 13 can enable a greater or smaller portion of the wave form 7 to be used to control current flow through the driving winding 3 and thus to control the forces applied to the balance wheel in each cycle to maintain it in oscillation.

The cyclic voltage generated in the windings 4 and 5 has an amplitude proportional to that of the oscillations and the rectifying and smoothing action of the transistor 15 and the condenser 13 causes the mean voltage across the condenser 13 to vary in accordance with the amplitude of the oscillations, the voltage increasing with decreasing amplitude of the oscillations and vice versa. The result is that the greater the amplitude of the oscillations, the smaller will be the current fed in each cycle to the driving winding 3 to tend to restore the oscillations to have a predetermined constant amplitude.

The control winding 4 is designed so that the voltage across its terminals is insufficient to switch the transistor 11 when the oscillation amplitude is such that the voltage across the condenser 13 is equal to the saturation voltage of the transistor 15.

The regulating winding 5 is designed so that the combined action of the windings 4 and 5 permits switching of the transistor 15 when the oscillation amplitude reaches a predetermined value, for example 220°. This enables the regulation to be such that no driving power at all can be delivered by the driving winding 3 if the oscillations are of sufficient amplitude without there having to be an element such as a resistance or a diode in series with the condenser 13 in the emitter/base circuit of the transistor 11.

The characteristics of operation depend mainly on the emitter/base voltage of the transistor 15 and on the voltages generated in the windings 4 and 5 which of course depend upon the characteristics of the magnets 2 and windings 6.

The higher the means amplitude of oscillation the more do the amplitudes vary with the value of the components and so for maximum stability it is preferable to have a mean oscillation amplitude which is not too high. This mean oscillation

amplitude varies inversely with the number of turns on the control and regulating windings 4 and 5 and if it is possible to choose a low number of turns for these windings it is possible similarly to ensure that the mean amplitude of oscillation for a large number of units constructed by a mass production method do not vary very much one from another.

The use of the negative voltage peak thus generated in the control winding 4 and used in the emitter/base circuit of the transistor 15 enables the number of turns in the regulating winding 5 to be kept low.

One way of winding the windings 3, 4 and 5 is shown in FIG. 5. The control and regulating windings are different parts of the length of a single winding and a tap 16 provides the common connection between them. This winding is coiled simultaneously with the driving winding 3 but does not have to have the same number of turns since winding of the winding 3 can be started after or finished before winding of the combined winding 4 and 5. The windings 3 and 4 may have the same number of turns to produce a corresponding phase relationship between them

FIG. 6 is similar to FIG. 5 but in this case the windings 3 and 4 have the same number of turns so that the winding operation has to stop once only, both for terminating the winding 3 and for withdrawing the tap 16.

The arrangement of FIG. 7 has the three windings wound simultaneously and in the preferred arrangement shown they all have the same number of turns.

In the arrangement of FIG. 8 the regulating winding 5 is wound with a number of taps 17 to 21, any one of which can be selected for connection to the base of the transistor 15. The control winding 4 has the maximum number of turns which enables complete removal of power from the driving winding 3, while the regulating winding 5 has such a number of turns that the maximum amplitude of oscillation will be about 250° if the tap 21 is used or about 200° when the tap 17 is used. The driving winding 3 will be calculated to give the smallest overall size of the winding consistent with the necessary driving torque for the oscillating balance wheel.

When setting up the arrangement of FIG. 8 the base of the transistor 15 is connected to the tap 21 and all the taps 17 to 21 are connected together. Taps are disconnected successively if the amplitude of oscillation is too high. The elimination of a connection increases the number of active turns of the winding 5 but gives rise to a decrease in the amplitude of oscillation by simultaneously reducing the number of short circuited turns.

The overall size can be reduced by choosing a high frequency of oscillation and indeed, since the generated voltage decreases with frequency, less turns are needed on the windings for higher frequencies.

On the other hand, higher frequencies increase the friction thereby requiring increased driving power but this is not important where, as in the present invention, there is an appreciable reserve especially if the supply voltage is relatively high as would be the case where it is used in a clock for a motor vehicle with a nominal 6, 12, or 24 volts battery. Of course an increase in the number of turns on the driving winding 3 to increase driving power requires an increase in the number of turns on the control winding 4 but not on the regulating winding 5.

The amplitude of oscillation depends upon the base/emitter voltage of the transistor 15 and this depends on temperature. Accordingly it is preferred that the magnets 2 and 2' have a temperature co-efficient which is negative and similar to that of the base/emitter junction of the transistor 15. For example, the magnets may be of ferrite and the transistor 15 of silicon. This arrangement makes the control and regulating circuit not very temperature-dependent so that the amplitude of oscillation is also not very temperature-dependent.

If the temperature co-efficient of the magnets is slightly more effective than that of the junction there can be a slight increase in amplitude with decreasing temperature which makes it possible to compensate for the increase in friction due to the thickening of lubricating oil at lower temperatures.

Although the transistors are shown as both being of the NPN type, it is possible for them both to be of the PNP type, or to be one of each type.

I claim:

1. A timing device comprising an oscillatory member, magnetic means on said oscillatory member, stationary control, driving, and regulating windings for co-operating with said magnetic means, a main transistor for controlling energization of said driving winding from a supply, said control winding being connected to control operation of said main transistor, and a bias circuit for said main transistor including a second transistor and said regulating winding for varying the bias of said main transistor in dependence on a characteristic of the oscillations of the member, said control and regulating windings being connected in series across two electrodes of said second transistor.

2. The device of claim 1 in which the oscillating device is a balance wheel.

3. The device of claim 1 in which said bias circuit further includes a resistance and a condenser and in which said second transistor has two electrodes connected across said condenser.

4. The device of claim 1 in which said control winding is in series in said bias circuit.

5. The device of claim 1 in which said oscillating member has means defining a dead-center position and in which during oscillations voltages are generated in said control and regulating windings, which voltages have a wave form which is symmetrical about the dead-center position.

6. The device of claim 1 in which said magnetic means and the threshold voltage of the second transistor vary in the same sense with changes in temperature.

7. The device of claim 1 in which said magnetic means comprise ferrite magnets and the second transistor is a silicon transistor.

8. The device of claim 1 in which said control and regulating windings comprise one length of wire co-axial with the other winding.

9. The device of claim 1 in which the three windings comprise three different wires coiled co-axially.

10. The device of claim 1 in which said regulating winding has a number of tappings enabling its effective length to be selected.

11. The device of claim 1 in which said magnetic means comprises two magnets arranged to co-operate with the windings in turn during an oscillation.

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