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Meyer

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[54] **ELECTROMAGNETIC DEVICE FOR MAINTAINING A MECHANICAL OSCILLATING OR ROTARY MOVEMENT**

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[52] **U.S. Cl.** **318/128,** 318/132
[51] **Int. Cl.** **H02k 33/00**
[58] **Field of Search** ....318/122, 119, 126–132; 58/23, 23 AO, 23 A, 23 V; 331/116, 116 M

[56] **References Cited**

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[57] **ABSTRACT**

An electromagnetic device for maintaining movement of an oscillating or rotating piece, such as the balance wheel of a timepiece, comprises a driving coil associated with a magnet on the piece. A contactor transistor in the feed circuit of the driving coil is controlled by a pick-up coil to deliver driving pulses to the driving coil. A regulating transistor acts on the contactor transistor to adjust the values of the driving pulses as a function of the desired speed of the piece. The emitter-base junction of the regulating transistor is connected to the terminals of the pick up coil and the regulating transistor is connected by its collector and its base to by-pass the base-emitter junction of the contactor transistor.

6 Claims, 6 Drawing Figures

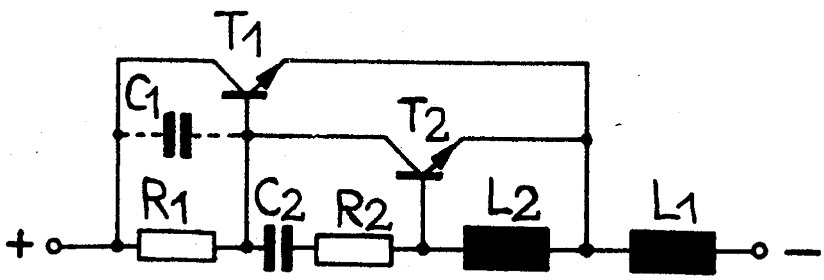

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Fig 1

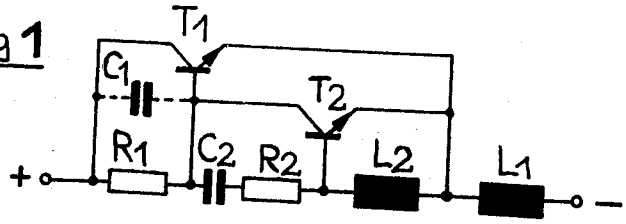


Fig 2

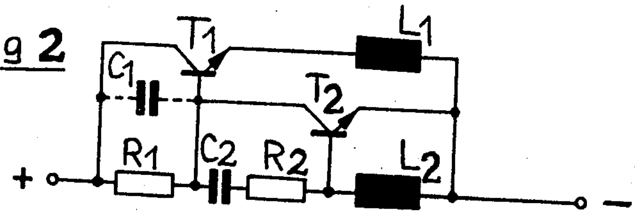


Fig 3

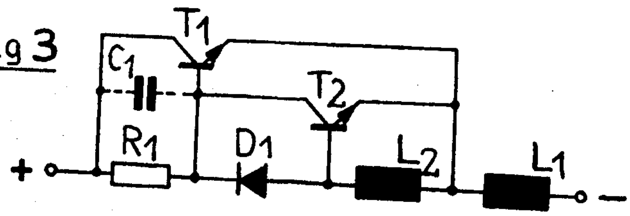
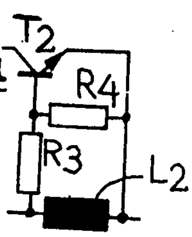


Fig 4a



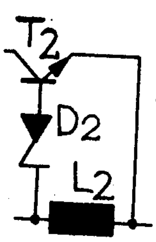
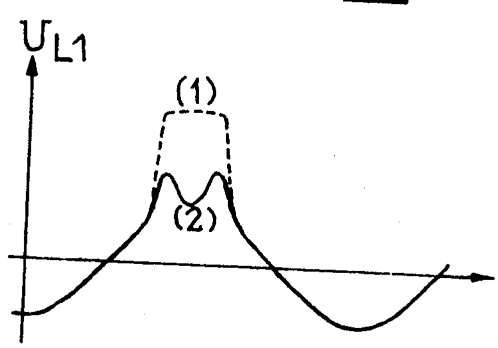


Fig 4b

Fig 5



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ELECTROMAGNETIC DEVICE FOR MAINTAINING A MECHANICAL OSCILLATING OR ROTARY MOVEMENT

The invention concerns electromagnetic devices, particularly applicable to horological instruments, for maintaining a mechanical oscillating or rotary movement, of the type comprising a pick-up coil and a driving coil interacting with a magnetic system, a driving transistor, and a transistor adjusting the maximal relative speed between the magnetic system and the coils.

The maximal speed of an oscillating system is proportional to its amplitude, which must be as constant as possible for the oscillator to have a good regularity of operation. For a rotating member, it is clear that the speed of rotation must also be as constant as possible.

Different types of regulation have already been proposed. The most usual consists of connecting the driving coil in series with a constant voltage supply, the circuit being closed by the emitter-collector connection of a junction transistor. Another consists of shunting the driving coil by an element limiting the voltage. In a third system, the driving coil is connected to the emitter of the transistor and a voltage-limiting element is connected to the base. For all of these circuits, in the case of an ideal regulation:

$U_i + RI = \text{constant}$

where U_i is the back electromotive force induced in the driving coil at the moment of the driving pulse, R is the resistance of the coil, and I is the current through the coil at the moment of pulse. As the power delivered at the moment of pulse is $U_i I$, it is seen that the relative speed between the magnetic system and the coils at the moment of pulse which speed is proportional to U_i, depends upon the charge. Hence, a change of the power of the source feeding the coils, for example wearing down of a cell, leads to modification of the regulation of the oscillating or rotating system.

To avoid this disadvantage, it has already been proposed to provide a third coil connected to the input of a regulating transistor the output of which is connected to the terminals of the pick-up coil, which results in shunting the pick-up coil as soon as the voltage induced in the regulating coil exceeds the cut-off of the regulating transistor. However, this type requires a supplementary coil which means an increase in the cost and the bulk, and additionally the regulating transistor damps the pick-up coil, causing a loss of power which is not negligeable especially taking into account that, for the low currents envisaged, the current gain of the transistor is reduced.

According to the invention, an electromagnetic device for maintaining movement of an oscillating or rotating piece comprises a driving coil associated with at least one magnetic element for ensuring maintenance of the said movement, a contactor transistor in the feed circuit of the driving coil, the contactor transistor being controlled by a pick-up coil to deliver pulses to the driving coil for maintaining movement of the piece, a regulating transistor acting on the contactor transistor to adjust the values of the said pulses as a function of a desired speed of the piece, the emitter-base junction of the regulating transistor being connected to the terminals of the pick-up coil, and the regulating transistor being connected by its collector and its emitter to by-pass the base-emitter junction of the contactor transistor.

The operating principle and embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a circuit diagram of a circuit according to the invention;

FIGS. 2 and 3 are variants thereof;

FIGS. 4*a* and 4*b* are examples of coupling elements between the pick-up coil and the regulating transistor; and

FIG. 5 is a graph of the voltage obtained at the terminals of the driving coil, as a function of time, with an assembly according to the invention.

A driving coil L_1 and a pick-up coil L_2 interact with a magnetic element such as a small permanent magnet or an oscillating or rotating piece (not shown). This piece could, for example, be the balance wheel of a timepiece which is caused to oscillate by means of a spiral hairspring. When the magnetic element passes by the coils L_1 and L_2, which can be coaxially wound on the same piece, an electro-motive force induced in the pick-up coil L_2 is amplified and supplied to the driving coil L1 to provide a pulse to maintain the motion of the oscillating or rotating piece.

An example of the feed circuit for coils L_1 and L_2 is shown in FIG. 1. A power source, such as a dry cell, is connected to the terminals of driving coil through the collector-emitter circuit of a first transistor T_1 called the "contactor" transistor. The base of collector-transistor T_1 is connected to the collector of a second transistor T_2, called the "regulating" transistor. The transistors T_1 and T_2 are preferably of the same type and may be of silicon. The pick-up coil L_2 is connected in the base-emitter circuit of the regulating transistor T_2, the emitter of which is also connected to the driving coil L_1.

At rest, the base of transistor T_1 is polarised by connection to the positive terminal of the cell through a resistor R_1 so that the transistor T_1 is slightly conducting. A capacitor C_1 can, if necessary, be included in series with resistor R_1 to eliminate parasitic oscillations. The bases of transistors T_1 and T_2 are connected by a capacitor C_2 and a resistor R_2 in series.

The operation of the device shown in FIG. 1 is hereinbelow described:

A slight electromotive force induced by the magnetic system upon relative displacement in relation to the pick-up coil L_2 is transmitted from the latter through the resistor R_2 and the capacitor C_2 to the base of the transistor T_1, and the driving coil L_1. The coils are both connected in the same direction so that there will be an increase of the relative speed, and consequently the amplitude in the case of an oscillating system.

The circuit is adapted to operate by pulses.

For as long as the electromotive force induced in the pick-up coil does not reach the cut-off voltage of the regulating transistor T_2, leaving the latter blocked, the voltage measured at the terminals of the driving coil L_1, designated by U_{L1}, will have the appearance of the curve (1) in FIG. 5. When the cut-off voltage of the regulating transistor T_2 is reached, this latter becomes conducting and thus reduces the emitter-base voltage of the transistor T_1, tending to cause blocking thereof. The pulse on the driving coil L_1 is thus greatly reduced and will have the appearance of the curve (2) in FIG. 5. The pulse "-hollow" is due to the effect of the counteraction thus obtained. The resistor R_2 improves the regulation by absorbing the slow transient oscillations of the latter.

The above-described regulation is very efficient and is practically independent of the supply voltage and the exterior mechanical load.

FIG. 2 shows a variant of the feed circuit with a different arrangement of the coils.

FIG. 3 shows another variant of the feed circuit characterized in that a diode D_1 replaces C_2 and R_2.

FIG. 4*a* shows a modified feed circuit in which resistors R_3 and R_4 are connected in series and parallel respectively between the base-emitter junction of transistor T_2 and the pick-up coil L_2. Resistor R_4 may have a negative temperature coefficient to shunt the emitter base circuit of the regulating transistor T_2 and compensate for the temperature effect in a determined temperature range. Resistor R_3 may be omitted, provides that the own resistance of coil L_2 be high enough.

In the modified circuit shown in FIG. 4*b*, a Zener-effect diode is connected in series between the pick-up coil L_2 and the base of transistor T_2. The Zener diode is chosen so as to ensure a temperature compensation of the device in a determined temperature range.

I claim:

1. (Once Amended) In an electromagnetic device for maintaining movement of a movable piece, said device comprising a driving coil associated with at least one magnetic element for ensuring maintenance of the said movement, and a contactor transistor in the feed circuit of the driving coil, the contactor transistor being controlled by a pick-up coil connected to its

base and collector circuit to deliver pulses to the driving coil for maintaining movement of the piece, the improvement comprising a regulating transistor acting on the contactor transistor to adjust the values of the said pulses as a function of a desired speed of the piece, the emitter-base junction of the regulating transistor being connected to the terminals of the pick-up coil, the regulating transistor being connected by its collector and its emitter to by-pass the base-emitter junction of the contactor transistor, and an impedance connecting only the bases of the two transistors.

2. In an electromagnetic device as defined in Claim **1**, wherein the contactor transistor is made slightly conductive by connecting its base to the positive terminal of the feed circuit through a resistor.

3. In an electromagnetic device as defined in claim **1**, wherein said impedance connecting only the bases of the two transistors is a capacitor and a resistor in series.

4. In an electromagnetic device as defined in claim **1**, wherein said impedance connecting only the bases of the two transistors is a diode.

5. In an electromagnetic device as defined in claim **1**, wherein a resistor having a negative temperature coefficient is connected to shunt the emitter-base circuit of the regulating transistor for the purpose of compensating for the temperature change effect in a determined temperature range.

6. In an electromagnetic device as defined in claim **1**, wherein a Zener-effect diode is connected in series between the pick-up coil and the base of the regulating transistor for the purpose of obtaining temperature compensation of the device in a determined temperature range.

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