United States Patent

[11] **3,568,017**

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[54] **PUSH-PULL OSCILLATOR FOR SUSTAINING THE OSCILLATIONS OF A RESONATOR**
5 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **318/128,** 318/130, 318/132, 58/23, 331/114
[51] **Int. Cl.** **H02k 33/10**
[50] **Field of Search** ..... 307/288, 313, 255; 58/28, 28 (A), 28 (B), 28 (C), 23, 23 (AO), 23 (FS); 318/127—133; 331/116, 116 (M), 114

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ABSTRACT: An electronic device for sustaining the oscillations of a resonator, especially for a timepiece, characterized by the fact that it comprises two complementary transistors the emitters of which are connected to the terminals of a source of current, the bases of which are both connected to one source of control pulses producing pulses alternatively of one sign and of the other, and the collectors of which are both connected to the element to be controlled, wherefore these transistors are operated alternatively by the pulses, one by the pulses of one sign and the other by the pulses of opposite sign, and so that the resonator thus receives a sustaining pulse at each half-oscillation of its oscillating member.

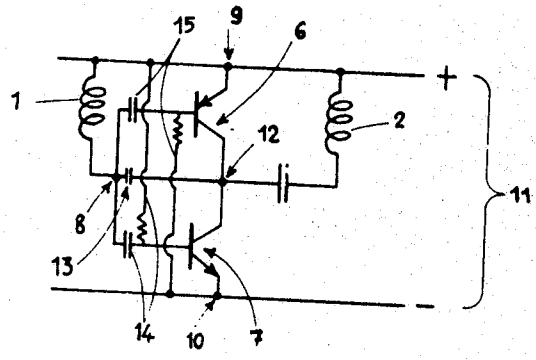
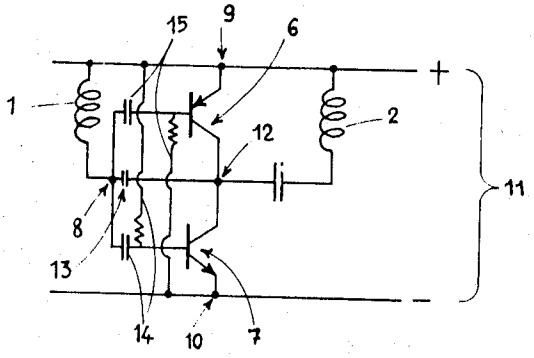


FIG. 1



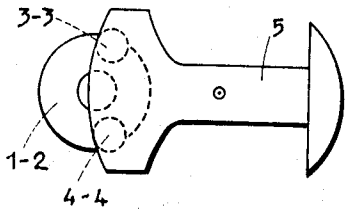


FIG. 2

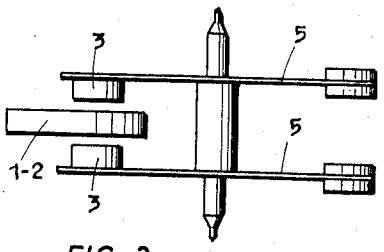


FIG. 3

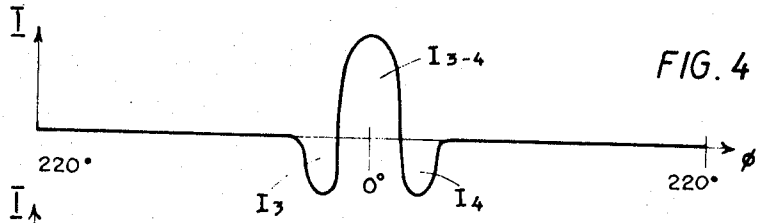


FIG. 4

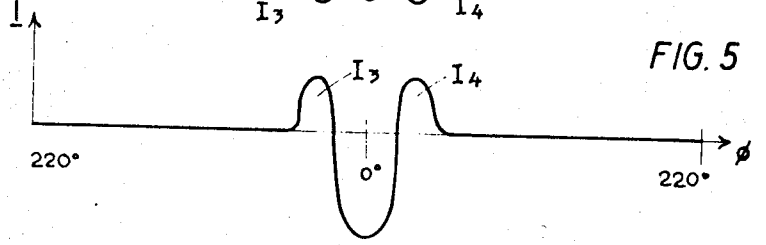


FIG. 5

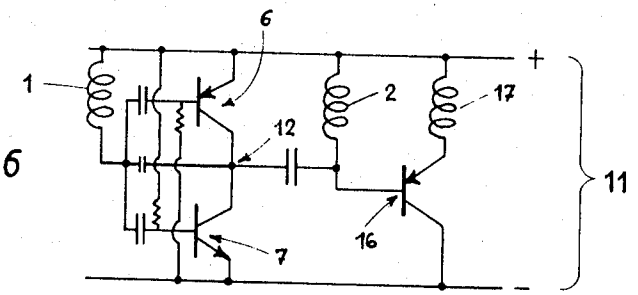


FIG. 6

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PUSH-PULL OSCILLATOR FOR SUSTAINING THE OSCILLATIONS OF A RESONATOR

The present invention relates to an electronic device for sustaining the oscillations of a resonator, especially for a timepiece.

The drawback of many devices for sustaining the oscillations of a resonator lies in the fact that these devices apply a sustaining pulse only once for each complete oscillation of the oscillating member of the resonator, like a detent escapement of a timepiece, which is unfavorable, especially in case the resonator is free and serves to control a second resonator, which is a driving one, driving the indicating elements of the timepiece.

As a matter of fact, a free resonator is very precise. But, it is necessary that the sustaining thereof be in perfect phase with the oscillations. If there is only one resonator and it operates also as a driving device, precision will be more difficult to achieve due to the damping which reduces the precision.

The object of the invention is to provide a sustaining device which applies a sustaining pulse at each half-oscillation of the oscillating member of the resonator, in the manner of a lever escapement, for compensating the error of phase of the sustaining.

The device according to the invention is characterized by the fact that it comprises two complementary transistors, the emitters of which are connected each to one of the terminals of a source of current, the two bases of which are both connected to a source of control pulses producing pulses alternatively of one sign and then of the other, and the collectors of which are both connected to the element to be controlled, all in such a way that these transistors are actuated alternatively by the pulses, one by the pulses of one sign and the other by the pulses of the opposite sign, the resonator thus receiving a sustaining pulse at each half-oscillation of its oscillating member.

The drawing shows, by way of example, two embodiments of the invention.

FIG. **1** shows diagrammatically a first embodiment of an electronic sustaining device applied to a driving balance-wheel for a timepiece.

FIG. **2** is a plane view of this balance-wheel.

FIG. **3** is an elevational view thereof.

FIG. **4** is a diagram of the current which is induced in the pickup winding of the device during a half-oscillation of the balance-wheel.

FIG. **5** is a diagram of the current which is induced in the said pickup winding during a half-oscillation in the other direction of the balance-wheel, and

FIG. **6** shows diagrammatically a second embodiment of an electronic sustaining device applied to a system comprising a free balance-wheel and a driving balance-wheel, of synchronization, for a timepiece.

The diagram of FIG. **1** shows a pickup winding **1** and a driving winding **2** represented in FIGS. **2**, and **3** as being superposed and cooperant with two pairs of magnets **3—3** and **4–4** respectively, carried by the two parallel and superposed arms **5** of a balance-wheel submitted to the action of a non-represented hairspring.

The sustaining circuit of the oscillations of this balance-wheel comprises a transistor PNP **6** and a transistor NPN **7**, the bases of which are both connected, at **8**, at one of the terminals of the pickup winding **1**. Each transistor has its emitter connected, at **9** and **10** respectively, at one of the terminals of a source of current **11**. The collectors of the two transistors are both connected, to **12**, at one of the terminals of the driving winding **2**. A capacitor **13** is interposed between the terminals **8** and **12** so as to constitute a counterfeedback intended to eliminate coupling which could occur at high frequency.

When the balance-wheel effects half an oscillation in one direction, from one of its extreme positions, there is produced, by induction, in the pickup winding **1**, when one of the pairs of magnets, for instance pair **3–3**, passes opposite one coil of this winding, a current, indicated by I_3 in FIG. **4**, followed by a current of higher voltage and of opposite sign I_{3-4} which is produced when, simultaneously, both pairs of magnets **3–3** and **4–4** pass opposite coils of the pickup winding, this current being followed by a new current of opposite sign I_4, produced when the pair of magnets **4–4** passes over the coil of the winding **1**.

During the return half-oscillation of the balance-wheel, in opposite direction, the current induced in the pickup winding **1** has the shape represented by the curve of FIG. **5**, which is the reverse of the one in FIG. **4**.

These several pulses are symmetrical with respect to the position of equilibrium of the balance-wheel, indicated by 0° in FIGS. **4** and **5**.

Each transistor is automatically polarized, by leads **14** and **15** respectively, so that only the voltages above a limit value release them. The result thereof is that, during the half-oscillations in one direction of the balance-wheel, one of the transistors is released by the pulses I_{3-4} pulses I_3 and I_4, of opposite sense, being insufficient for releasing the other transistor, which is released, alone, during the half-oscillations in the reverse direction of the balance-wheel.

Thus, at each half-oscillation, at the passage of the balance-wheel through its position of equilibrium, a driving pulse is applied thereto.

The circuit represented in FIG. **6** is identical to that of FIG. **1**, with the only difference being that a third transistor, designated by **16**, is added thereto, the base of which is connected at point **12** of the junction of the collectors of the transistors **6** and **7**, and the emitter of which is connected to the driving winding **17** of a second resonator.

In this embodiment, the first resonator, cooperating the pickup winding **1** and with the driving winding **2**, is free and serves to control or synchronize the second resonator which is driving. This arrangement has a great advantage, from the point of view of precision, due to the fact that factor Q of the control balance-wheel, which is free, can be six to 10 times higher than that of a driving balance-wheel from which energy is subtracted, at each oscillation, for the driving of the indicating elements of the timepiece.

I claim:

1. In a timepiece having a pair of parallel superposed arms of an oscillating balance wheel subject to the action of a hair spring, an electronic device for sustaining the oscillations of a resonator comprising:

a pickup winding as a source of control pulses for producing alternating pulses of one sign and of opposite sign;

a driving winding connected to the element under control and superpose over the pickup winding;

a source of current;

a pair of magnets mounted on each arm of the balance-wheel;

a capacitor interposed between the pickup and driving windings, the sustaining circuit of the oscillations including first and second complementary transistors of opposite conductivity type having bases connected to the pickup winding and emitters connected to the source of current and collectors connected to the driving winding; and

with the transistors being operative alternatingly, one by the pulses of one sign and the other by the pulses of opposite sign enabling the resonator to receive a sustaining pulse at each half-oscillation of the balance wheel.

2. In the electronic device of a timepiece as set forth in claim **1**, characterized by the first transistor being released by the pulses of one sign as the half-oscillations of the balance wheel move in one direction and by the second transistor being released by the pulses of the said one sign as the half-oscillations of the balance wheel move in opposite direction.

3. In the electronic device of a timepiece as set forth in claim **2**, with the application of a driving pulse at each half

oscillation of the balance wheel through its position of equilibrium.

4. In the electronic device in a timepiece as set forth in claim 2, with the balance-wheel making a half-oscillations in one direction for producing in the pickup winding a current of one sign as one of the pairs of magnets passes the coil thereof and a current of higher voltage and opposite sign as both of the pairs of magnets pass the coil thereof and another current of opposite sign as the other of the pairs of magnets pass the coil thereof and with the balance wheel making a return half oscillation in opposite direction producing a reverse current.

5. In a timepiece having a balance wheel subject to the action of a hair spring, an electronic device for sustaining the oscillations of a resonator comprising:

a pickup winding as a source of control pulses for producing alternating pulses of one sign and of opposite sign;

a driving winding connected to the element under control and superposed over the pickup winding;

a source of current;

a pair of magnets mounted on the balance wheel;

a capacitor interposed between the pickup and driving windings, the sustaining circuit of the oscillations including first and second complementary transistors of opposite conductivity type having bases connected to the pickup winding and emitters connected to the source of current and collectors connected to the driving winding; and

with the transistors being operative alternatingly, one by the pulses of one sign and the other by the pulses of opposite sign enabling the resonator to receive a sustaining pulse at each half-oscillation of the balance-wheel.