CIRCUIT ARRANGEMENT IN AN ELECTRONIC WATCH EMPLOYING A BALANCE

FIG. 2
In combination with an electronic watch wherein the balance staff carries an oscillating permanent magnet, the oscillations of which induce impulses in a control winding which impulses are returned to the magnet through a driving winding. For amplification, a first circuit, a source of electrical energy including positive and negative terminals feeding energy in the circuit, a first transistor inserted through its emitter and collector in the circuit between the terminals, a first resistance between the emitter of the transistor and the base of the transistor, a second circuit connecting the emitter of the transistor with the negative terminal connected with the collector of the transistor, a further resistance inserted in the second circuit, a shunt circuit connecting a point of the second circuit located between the emitter of the transistor and the further resistance with the base of the transistor, a control winding in the shunt circuit, a condenser inserted in the second circuit between the emitter of the first transistor and the further resistance, the charging of the condenser producing during transient oscillatory periods of the watch on the base of the first transistor a potential such that it makes the latter operate as a Class A amplifier; a second circuit set across the terminals in parallel with the first transistor and the first resistance, a second transistor in series with the first transistor to provide the amplification, a second upkeep winding between a collector of the second transistor and the corresponding negative terminal, means connecting directly the base of the second transistor with the emitter of the first transistor, the rating of the further resistance being such that during the transient oscillatory periods of the watch, the second transistor operates as a Class A amplifier, the two transistors operating as Class B amplifiers during the normal operative periods of the watch as soon as the first mentioned condenser has lost the major part of its load and is at a voltage lower than the threshold voltage of the first transistor.

In order to remove the drawbacks appearing when starting such a mechanical oscillator, circuits have been proposed which include one or two transistors through which a voltage is applied, under the control of a manual or a taste, or else, of a voltage divider incorporated with the circuit, to the base of at least one transistor in a manner such that the inoperative current passing through the upkeep winding increases until it reaches a value such that it is capable, for transient conditions, to start the oscillatory movement of the balance wheel and to bring it into permanent operative conditions for which the amplitude of oscillation remains at a constant value.

The first solution proposed has the drawback of requiring the intervention of an operator for each start of the watch, whereas the second solution does not furnish a sufficient biasing voltage to use silicon transistors of which the great thermal stability and lower cost makes them preferable to the standard germanium transistors.

The present invention has for its object an electronic watch of the type claimed in said U.S. patent.

According to the present invention and as illustrated in the accompanying FIGURE 1, a first transistor has its emitter connected in one of the poles of the battery through a resistance 2, while in the base emitter circuit of said transistor there is inserted a control winding 12 and a condenser 4 which is loaded through said resistance 2 and a further resistance 1 by the supply of current. The loading voltage produced by the mechanical oscillations of the system during its transient operative conditions applies on the base of the transistor T1 a potential such that the latter operates as a Class A amplifier. In the collector circuit of a second transistor T2 is inserted the upkeep winding 13 while its emitter-base circuit includes the resistance 2, the base of said transistor T2 being connected with the emitter of the transistor T1, said transistor T2 operating during the transient oscillating conditions of the mechanical system under class A conditions also. In contradistinction, during the oscillations under permanent conditions, the two transistors T1 and T2 operate as Class B amplifiers, since the condenser 4 which has lost a large fraction of its load remains at a voltage lower than the threshold voltage of the transistor T1.

The accompanying drawings illustrate, by way of example, an embodiment of the present invention.

In said drawings:

FIGURES 1 and 2 are two wiring diagrams corresponding to said invention.

The circuit according to FIGURE 1 includes as already mentioned a supply of current S, a control winding 12, an upkeep winding 13 and two transistors T2 and T1; the base emitter circuit of the transistor T1 includes the control winding 12 and a condenser 4 which is loaded through the resistances 1 and 2. The condenser 5 is inserted between the base and the collector of the transistor 1. A resistance 3 is inserted in the feed circuit.

The transistor T2 includes in its base-emitter circuit the above-mentioned resistance 2 and in its collector-emitter circuit the control winding 13 and the supply of current S.

The base of the transistor T1 is connected with the negative pole of the battery through the agency of the control winding 12 and of the resistance 1. The rating of the latter is such that, in the absence of any oscillation and during transient operation, said transistor operates as a Class A amplifier.
The transistor T2 the base of which is connected directly with the emitter is adapted to operate also as a Class A amplifier, its gain is very high, even for extremely weak signals. Said gain is sufficient for the least fluctuation of the current in the upkeep winding to produce small movements of the balance wheel as in initiation of the starting of the oscillations of the spiral spring and balance wheel system. The variations of the current produced by the background noises in the transistor are, for instance, sufficient for initiating the mechanical oscillatory movement.

On the other hand, the least movement of the balance wheel induces a small electromotive force in the control winding, which, after amplification, starts the mechanical oscillations. The small shifting of the balance wheel produces the establishment of the current defining operation as a Class A amplifier is sufficient for starting such oscillations.

The two phenomena referred to make it possible to reliably obtain under any conditions whatever the self-starting of the oscillations of the spiral spring and balance wheel system.

Upon energization of the circuit, the condenser 4 is loaded through the resistances 1 and 2. Its loading voltage is stabilized transiently at a value which is slightly larger than the threshold voltage across the base and emitter of the transistor T1 which starts this operation under Class A conditions.

From this moment onwards, the balance wheel 14 begins oscillating. As the amplitude of mechanical oscillations increases, the electromotive force induced in the control winding 12 increases also proportionally to the speed of the magnet 11 and consequently the control current in the emitter base circuit of the transistor T1 also increases.

Said current passes also through the condenser 4 in a direction such that for each current pulse the condenser loses a fraction of its load. If the resistances 1 and 2 are correctly rated, the voltage across the terminals of the condenser decreases gradually down to a value lower than the threshold voltage across the base and emitter of T1 which operates now as a Class B amplifier or even as a Class C amplifier.

The transistor T1 requires thus practically no current between the successive pulses.

During the interval between two successive pulses, the current reloading the condenser 4 remains very low by reason of the large value given to the resistance 1; there is obtained across the terminals of the resistance 2 a drop in voltage which is much lower than the threshold voltage between the base and the emitter in the transistor T2, which latter operates now as a Class B amplifier.

In order that the amplitude of oscillation of the balance wheel 14 during permanent operative conditions may be independent of any dispersion of the properties of the transistor and in particular of the gain of current, it is sufficient that during the driving pulse the transistor T2 may be saturated. As a matter of fact, in such a case the current pulse in the upkeep winding 13 is limited to a practically constant value by the ohmic resistance of said winding.

Similarly, the resistance 3 inserted between the collector of T1 and the negative pole of the battery allows limiting the current in the emitter circuit of said transistor to the value required for a reliable and accurate operation of the transistor T2.

This allows reducing substantially the consumption of current by the amplifier.

The condenser 5 inserted between the collector and the base of the transistor T1 ensures the cutting out of the high frequency electric oscillations produced by the direct magnetic coupling between the control and upkeep windings.

The direct connection between the resistance 1 and the transistor collector T2 produces a negative reaction which ensures a stabilization of the inoperative transistor current under the conditions of Class A. As a matter of fact, if the inoperative current T2 is too high, the voltage of its collector drops and consequently the biasing of T2 also drops. The reverse phenomenon is obtained.

The variable resistance 6 inserted in series with the upkeep winding allows adjusting the amplitude of the oscillations of the balance wheel and spiral spring system.

The leak current from the alloyed or diffused silicon transistors which is extremely low remains negligible with reference to their operative current within a range of temperatures rising up to very high temperatures. Because of the high leakage currents of germanium transistors over 40° C. it is advantageous that the present device avoids their use. Another advantage of the present device is that it is suitable to operate silicon transistors rated at 20 thereby giving an amplifying coefficient of 400 than to use a single transistor rated at 300 or 400.

What is claimed is:

1. In an electronic watch a balance staff carrying a coil support on each of its ends a balance wheel mounted on said staff located between said coil supports, an oscillating permanent magnet, the oscillations of which induce impulses in a control winding, which impulses are returned to said magnet through a driving winding after amplification; a first circuit, including a source of electrical energy having positive and negative terminals feeding energy into said circuit, a first transistor having a predetermined threshold voltage inserted through its emitter and collector in said circuit between said terminals, a first resistance inserted between the emitter of the said transistor and the corresponding terminal, a second circuit connecting the emitter of said transistor with the negative terminal connected with the collector of said transistor, a further resistance inserted in said second circuit, a shunt circuit connecting a point of said second circuit located between the emitter of said transistor and said further resistance with the base of said transistor, a watch containing the inoperative current limiting above said permanent magnet and mounted on one of said coil supports, a condenser inserted in said second circuit between the emitter of the first transistor and said further resistance, the charging of the condenser producing during the transient oscillatory periods of the watch on the base of the first transistor, a potential such as will make the latter operate as a Class A amplifier, a third circuit fed across said terminals in parallel with said transistor and first resistance, a second transistor in series with said first transistor to provide said amplification, a second upkeep winding mounted on the other end of said coil supports and below said permanent magnet and inserted between the collector of the second transistor and the corresponding negative terminal, means connecting directly the base of the second transistor with the emitter of the first transistor, the rating of the further resistance being such that during the transient oscillatory periods of the watch, said second transistor operates as a Class A amplifier, the two transistors operating as Class B amplifiers during the normal operative periods of the watch as soon as the first mentioned condenser has lost the major part of its load and is at a voltage lower than said threshold voltage of the first transistor.

2. The combination according to claim 1, having an auxiliary condenser between said base and said collector thereof of said first transistor to damp high frequency oscillations.

3. The combination according to claim 1, wherein said
third circuit includes a first section leading to said positive terminal and a second section in common with the part of said second circuit leading to said negative terminal.

4. The combination according to claim 3, having a variable resistance in said third circuit between the collector of said second transistor and said second upkeep coil.

5. The combination according to claim 1, having an auxiliary resistance between the collector of said first transistor and said negative terminal whereby to limit the current in said collector,

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