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# PATENT SPECIFICATION

DRAWINGS ATTACHED

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Int. Cl.:—C 04 c 3/00.

## COMPLETE SPECIFICATION

## Improvements in Electrical Circuitry for Timekeeping Instruments

We, THE UNITED STATES TIME CORPORATION, a Corporation organized under the Laws of the State of Connecticut, United States of America, of Waterbury 20, Connecticut, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

The present invention relates to timekeeping instruments, and more particularly to a battery driven watch.

The prior art includes many electronic circuits adapted for timekeeping. In one such circuit, Patent Specification No. 926,419, an oscillative coil acts as a pick-up coil and drive coil and co-operates with several stationary, permanent magnets. The coil is a part of a monostable multivibrator circuit. The circuitry shows two transistors arranged complementary to each other, i.e., PNP and NPN, and a battery source.

In this arrangement both transistors are continuously blocked in the rest position of the vibrator. Therefore, this system is notselfstarting. During the mechanical vibrations of the system both transistors are opened by the impulse generated in the coil; however, the coil current flows only through one transistor. Another current flows through the other transistor parallel to it which is useless for the impulse, in the considerable amount of at least 20% or more of the total current. This means that, compared to the circuit of the present invention, a specific battery has a shorter lifetime or that for a determined lifetime a larger battery has to be used.

It is an objective of the present invention to provide an electric circuit for a timepiece which is relatively inexpensive, has few parts, is small and has a relatively low battery consumption.

In accordance with the present invention there is provided a timekeeping instrument including a permanent magnet, a coil acting as a pick-up coil and as a drive coil, means mounting the magnet and the coil for relative mechanical oscillation, a source of direct current, an astable multivibrator circuit consisting of first and second complementary transistors, and an R.C. network, wherein the magnet and the coil are part of a mechanical oscillating system, the emitter of the first transistor is connected to the emitter of the second transistor, the collector of the second transistor is connected to the one end of the coil, and the collector of the first transistor is connected to the current source. The total coil current flows through the exit sides of both transistors and only a very small part is branched off for triggering and does not impulse the coil. There is obtained an optimum efficiency and a maximum lifetime of the battery, which is an important advantage for wristlet watches.

A damping condenser can be provided which preferably will be in parallel with the coil for the suppression of high frequency oscillations.

It is furthermore advantageous to connect a coupling resistor between the base of the second transistor and the other end of the coil. This circuitry becomes unstable due to this resistor, which means that a constant, electric vibration occurs independently from the relative motion between coil and magnet.

Since this unstable electrical system causes vibration by itself, without a physical impulse from the outside, the mechanical oscillating system of the timekeeping

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instrument starts by itself. This is an advantage since, under unfavourable conditions, such a mechanical system can come to a stop for a short time due to external influences such as shock.

The self-starting and also the vibration impulses of the circuitry are particularly favourable when the ohmic resistance of the coupling resistor is a multiple of the ohmic resistance of the coil. In order that the mechanical oscillation system performs synchronization of the circuitry, the frequency of the free running, unstable multivibrator should be lower (at maximum equal) than the inherent mechanical frequency of the vibrating system.

Other objectives of the present invention will be apparent from the description of the preferred embodiment of a timekeeping instrument according to the invention described below in conjunction with the accompanying drawing which shows schematically the relevant construction and electrical circuitry of the embodiment.

A permanent magnet, 10, is fixed on the free end of a spring 12. The opposite end of the spring is firmly connected with a stationary part of the timekeeping instrument (not further shown). The magnet 10 vibrates forwards and backwards, corresponding to the double arrow A. The magnet 10 co-operates with a stationary coil 14 which serves simultaneously as a pick-up coil and drive (impulse) coil. In this connection it should be mentioned that only for reason of easier representation the magnet is shown as movable, but usually the magnet is stationary and the coil is oscillative and impulses the timekeeping instrument.

One end of the coil 14 is connected to the plus terminal of a D.C. (battery) source 16. The minus terminal of the D.C. source is connected over the collector — emitter path of a PNP transistor 18. The emitter — collector path of an NPN transistor 20 is connected with the other end of the coil 14. Both transistors 18 and 20 can be exchanged against each other, only the battery terminals would then have to be changed correspondingly. Another current circuit leads from the plus terminal of the D.C. source through a resistor 22 to the base of the transistor 20, thence through the emitter of the transistor 20, the emitter of the transistor 18, the base of the transistor 18 and finally through a resistor 24 to the minus terminal of the current source. Furthermore, the base of the transistor 18 is connected through a condenser 26 with the collector of the transistor 20 and with one end of the coil 14.

Another condenser 30, shown by a dash-dotted line, may be provided which suppresses high frequency current. It is arranged parallel to the coil 14.

In the folowing mode of action of the circuit will be explained in detail.

In the rest position, when magnet 10 is not moving, the current source 16 is switched on by a switch (not shown). Condenser 26 begins to charge over the charging circuit formed by the coil 14 and the resistor 24, and can be charged up to the voltage of the current source. A negative voltage is therefore placed on the base of the transistor 18, which means the D.C. voltage acts on the collector so that the transistor 18 becomes conductive. The base of the transistor 20 has applied to it the full positive voltage of the current source 16, so that the base and the collector have the same voltage, which means the transistor 20 is open (is ready to conduct).

As soon as both transistors 18 and 20 start to be open, a current from the current source 16 begins to flow through the coil 14 and the collector-emitter paths of both transistors 18 and 20. A reciprocal physical impulse effect between the coil 14 and the magnet 10 occurs and, in the present example, an impulse will be given to the magnet 10.

Since also the collector — emitter path of the transistor 18 becomes conductive, the condenser 26 can be discharged through the emitter — base-path of the transistors 18 and 20, so that the voltage impulse in the coil 14 rises rapidly to provide the maximum impulse. After the discharge of the condenser 26 the impulse collapses rapidly. By this relative motion between coil and magnet at the mechanical inherent frequency of the vibrating system, control pulses are induced in the coil.

The condition after the starting of vibration will now be explained.

When the electrical pulse in the coil 14 has collapsed after the start of mechanical vibration, the transistor 18 is blocked because the base of transistor 18 is more positive than the collector. The emitter of transistor 20 is cut off from the negative voltage terminal of the battery 16. With the presence of the resistor 22 the transistor 20 is also blocked because it's base is more negative than the collector.

When an electrical pulse is created in the coil 14 by the relative movement of the coil and magnet the voltage at the base of the transistor 18 becomes more negative by means of the charging of the condenser 26 and transistor 18 will be opened. Now a current can flow over the base-emitter path of the transistor 20 so that the current circuit from the coil 14 through the transistor 20, transistor 18 to the source of the current 16 is completed. The impulse current necessary for the impulse of the vibrating system is flowing.

The length of the electrical pulse in the coil which produces the mechanical impulse is determined by the characteristic of the rate of discharge of the condenser 26, which is discharged over both transistors. After the discharge of the condenser the preceding condition appears again, this means the more positive base compared to the collector blocks the transistor 18, and by that, also the transistor 20.

The interval between the electric impulses is determined by the characteristic of the rate of charge of the condenser. The condenser is chosen so that its discharge time is longer, or at most equal, to the period of the mechanical vibration system. The synchronization and triggering of the impulse circuitry will therefore occur by the mechanical vibration system.

The resistor 24 is relatively large e.g., in the magnitude of 1 M Ohm and the resistor 22 is of a smaller magnitude, for example of 100 K Ohm. The capacitor 26 is of the magnitude of 1/10 microfared.

By the indicated values and using appropriate transistors and an appropriate coil, mechanical vibration systems in a frequency range of between 200 and 500 periods per second can be synchronized.

Modifications may be made in the present invention within the scope of the subjoined claims. For example. as already mentioned either the coil or magnet, or both, may be movable.

WHAT WE CLAIM IS:—

1. A timekeeping instrument including a permanent magnet, a coil acting as a pick-up coil and as a drive coil, means mounting the magnet and the coil for relative mechanical oscillation, a source of direct current, an astable multivibrator circuit consisting of first and second complementary transistors, and an RC network, wherein the magnet and the coil are part of a mechanical oscillating system, the emitter of the first transistor is connected to the emitter of the second transistor, the collector of the second transistor is connected to one end of the coil, and the collector of the first transistor is connected to the current source.

2. A timekeeping instrument according to Claim 1, wherein a damping condenser is provided across the coil for the suppression of high frequency oscillations.

3. A timekeeping instrument according to Claim 1, wherein a coupling resistor is arranged between the base of the second transistor and the end of the coil not connected to the collector of the second transistor.

4. A timekeeping instrument according to Claim 3, wherein the ohmic resistance of the coupling resistor is a multiple of the ohmic resistance of the coil.

5. A timekeeping instrument according to Claim 1 wherein the astable multivibrator is free running and the RC network is dimensioned such that its frequency is at maximum as high as the mechanical inherent frequency of the vibrating system.

6. A timekeeping instrument incorporating electrical circuitry, substantially as hereinbefore described with reference to the accompanying drawings.

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