United States Patent

Vosseler

[15] **3,668,442**

[45] **June 6, 1972**

[54] **RESONATORS FOR DRIVING TIMEPIECE GEAR TRAINS**

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[22] Filed: **Apr. 26, 1971**

[21] Appl. No.: **137,359**

[30] **Foreign Application Priority Data**

Apr. 27, 1970 Switzerland 6261/70

[52] **U.S. Cl.** ....**310/8.2,** 58/23 TF, 310/8.5, 318/130, 318/132

[51] **Int. Cl.** **H01v 7/00**

[58] **Field of Search**........................310/8.1, 8.2, 8.3, 8.5, 8.6, 310/25; 331/116, 155, 156; 318/129, 130, 131, 132; 58/23 R, 23 TF, 23 V, 23 AO, 23 D

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[57] **ABSTRACT**

A timepiece resonator comprises mechanically connected first and second oscillating crystals connected respectively in the collector-emitter and collector-base circuits of a transistor. At least the first crystal is secured to a blade adjacent to a clamping point of the blade, and a free end of the blade, carrying driving means for cooperation with a pinion, oscillates at a sub-harmonic of the resonant frequency of the crystals.

10 Claims, 4 Drawing Figures

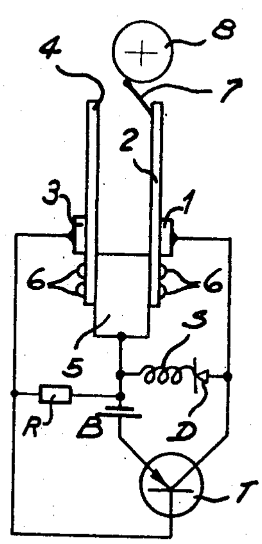
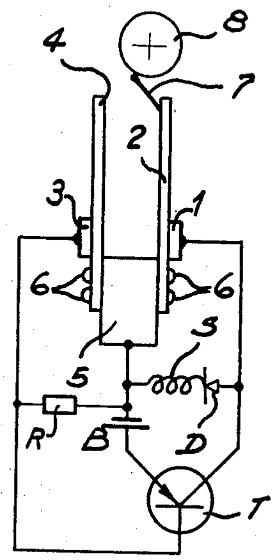


Fig 1



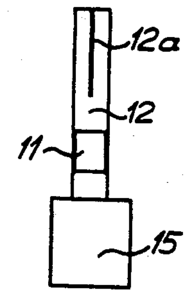


Fig 4

Fig 2

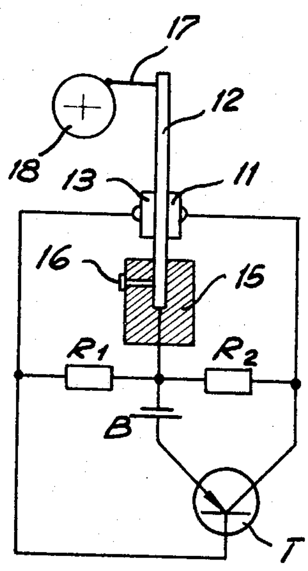
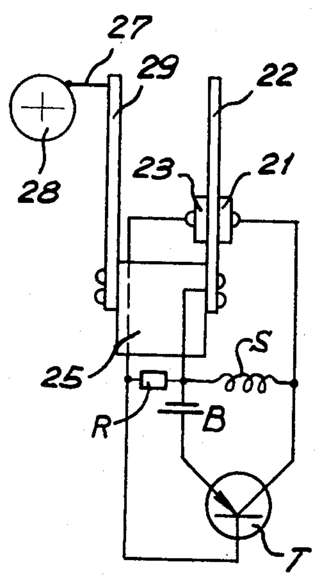


Fig 3



RESONATORS FOR DRIVING TIMEPIECE GEAR TRAINS

This invention relates to resonators, in particular to resonators for driving timepiece gear-trains, and comprising a resonator circuit including mechanically connected crystal oscillators respectively connected in the emitter-collector and base-emitter circuits of a transistor.

Such resonators are already described in U.S. Pat. Nos. 3,176,167 and 3,343,365 and may, in particular, be used directly to drive a timepiece gear train by causing a transmission member secured to the free end of one oscillating crystal to act directly on the first pinion of the gear train in the manner of a driving pawl.

These resonators have a very simple circuit construction, since the oscillating circuit requires neither coils nor capacitors. There are drawbacks, however, in that the oscillation amplitude of the driving crystal is only about 10 microns and its oscillation frequency lies generally in the kHz range. For this reason, the pinion must be very fine-toothed to suit the low oscillation amplitude, and the number of teeth and the diameter of the pinion must be relatively large, since otherwise the rapidly oscillating blade would drive it too fast and the reduction gearing would have to be unduly large. In addition, the transmission member driving the pinion must be very finely and sturdily engineered, since it is subject to considerable stress as a result of the high frequency.

It is an aim of the present invention to remedy the indicated drawbacks of resonators of the abovementioned type and to provide a resonator which, without any additional electrical components, has a reduced frequency and increased amplitude, and which employs only oscillation crystals of very small size in order to reduce costs due to the relatively expensive material of the crystals.

According to the invention, there is provided an electric resonator, in particular for driving timepieces, comprising a resonator circuit comprising a transistor having an emitter-collector circuit and a base-emitter circuit, a first crystal oscillator in the emitter-collector circuit, and a second crystal oscillator in the base-emitter circuit, means mechanically coupling the first and second crystals for the transmission of mechanical oscillations of one to the other, and a flexible blade having a free end and being clamped to a holder, in which at least said first crystal is secured to said blade adjacent the point of clamping the blade to the holder, and the length of the blade is greater than the largest dimension of said first crystal such that said free end oscillates at a sub-harmonic frequency of the resonant frequency of said resonator circuit.

The following technical advantages can be obtained using an oscillator according to the invention:

a. The resonator circuit may be operated at the relatively high frequency of 1,000 Hz or more, which is a normal frequency for crystal oscillators, whereas the free end of the blade oscillates at a substantially lower frequency, below 1,000 Hz, and with an amplitude of a few tenths of a millimeter. This allows a pinion of ordinary size and without specially fine toothing to be used when a transmission member cooperating with the toothing is secured to the end of the blade in the known way.

b. The mass of the oscillating resonator may be suitably increased by modifying the size of the blade, which may be made of an economical, commercially available material, without the need for a large quantity of the relatively expensive oscillating crystal material.

c. The blade is advantageously provided in a material with a low temperature coefficient such as the alloy known under the trade mark "NIVAROX", a suitable steel alloy, or even a plastic. This procedure will substantially counteract the undesirable temperature-dependence of the oscillatory behavior of piezoelectric crystals, since the oscillatory behavior of the resonator according to the invention is determined almost entirely by the dimensions and material of the flexible blade.

d. The resonator is very simple to assemble, since the blade may be secured merely by means of screws. Previously crystal oscillators had to be adhesively secured to their holders at the clamping point, which is a very laborious process. The method of securing the transmission member driving the first pinion of a watch gear train is also simplified. This member need no longer be carefully stuck to the crystal, but may be attached in any suitable way to the free end of the blade, the material of which can be machined more easily and more accurately than that of the crystal.

e. Since the delicate crystal oscillator is to some extent reinforced by being secured to the blade, the mechanical construction of the resonator is quite sturdy.

Further features of the invention will be found in the claims.

Several embodiments of the invention will now be described, by way of example, with reference to the accompanying schematic drawings, in which:

FIG. 1 shows a first embodiment of resonator with two flexible blades clamped in a common holder and with a crystal oscillator secured to each of them;

FIG. 2 shows a second embodiment with two crystal oscillators secured on opposite sides of a blade;

FIG. 3 shows a third embodiment with an additional blade, independent of the electric resonator circuit, caused to oscillate only via the material of the holder; and

FIG. 4 is a side elevation of a modified blade with a longitudinal slit in its free end.

In FIG. 1, one end of each of two flexible metal blades **2** and **4** is secured by screws **6** to a holder **5**, which may, for example, be a block of metal fixed to a watch frame. To one side of each blade **2**, **4** is adhesively secured an crystal oscillator **1**, **3** respectively, with crystal **1** connected in the emitter-collector and crystal **3** in the emitter-base circuit of a transistor T. A battery B in the emitter circuits of the transistor forms a current source. The size of the crystals is a fraction of the length of the blades. To the free end of blade **2**, forming a driving resonator, is secured a transmission member **7**, which drives a gear wheel **8** of the gear train of a timepiece (not shown in detail). Member **7** may, for example, be a wire with a jewel secured to the end engaging in the teeth of gear wheel **8**. Crystals **1** and **3** are mechanically interconnected via the material of blades **2** and **4** and holder **5**, the resonator circuit operating in the same way as the known circuit described in U.S. Pat. No. 3,176,167, except that the free ends of the blades oscillate at a sub-harmonic of the frequency of the resonator circuit.

To damp the peaks of the pulses generated by the crystals due to the piezoelectric effect, a coil S is connected in parallel to crystal **1**, and in series with a diode D. This arrangement may be dispensed with, however. Crystal **3** is electrically connected in parallel to a resistor R.

If the blades **2** and **4** and holder **5** are of metal and, in addition, if an electrical connection is provided between the blades and the internal electrodes of the crystals, for example by the use of an electrically conductive adhesive, both internal electrodes of crystals **1** and **3** are electrically connected together and to the oscillator circuit via the material of the blades and the holder. It is not, however, absolutely essential to have an electrical connection between the internal electrode of a crystal and the appropriate blade, because, in this case, the existing capacitive coupling is sufficient. If holder **5** is not made of electrically conductive material, a special electrical connection to the blades is, of course, necessary. If the blades are not made of an electrically conductive material, either electric leads to the internal electrodes of the crystals may be provided, or the blades may be metallized where they join the crystals. The same applies to the embodiments shown in FIGS. **2** and **3**.

In the embodiment of FIG. **2**, two crystal oscillators **11** and **13** are secured to opposite sides of a blade **12**, one end of which is clamped by a screw **16** in a holder **15** and the other free end of which carries a transmission member **17** actuating the first gear wheel **18** of a watch gear train. Once again, the crystals **11**, **13** are respectively connected in the emitter-collector and emitter-base circuits of a transistor T, and each crystal is connected in parallel to a resistor R1 or R2.

In the embodiments of FIG. 3, a flexible blade **22** carrying crystal oscillators **21** and **23** at opposite sides and a further flexible blade **29** are secured to a holder **25**, blade **29** forming a driving resonator. Blade **29** is independent of the resonator circuit and, as a result of the mechanical connection via the material of holder **25**, which acts as a resonator base, is caused to oscillate and carries a transmission member **27** driving a pinion **28**. The time base and the driving component are thus separated, and hence there is virtually no feedback from the gear train to the resonator circuit. Once again, crystals **21** and **23** are respectively connected in the emitter-collector and emitter-base circuits of a transistor T. A coil S is connected in parallel to crystal **21** and a resistor R to the crystal **23**.

As shown in FIG. **4**, the free end of any of the blades, e.g., blade **12** in FIG. **2**, may be provided with a longitudinal slit **12*a*** terminating away from the point at which a crystal **11** is secured. Such a longitudinal slit increases the flexibility and resonance of the oscillating blade.

Tests on an resonators according to the invention have shown the following:

If two blade-shaped crystal oscillators are used in the known way, the oscillation frequency of the crystals is about 3 kHz and the amplitude only about 0.01 mm. For a resonator of the type shown in FIG. **1** with "NIVAROX" blades 16 mm long and 1 mm thick and having crystals 0.7 mm thick and about 4 mm long adhesively secured thereto, the free ends of the blades oscillate at a frequency of only 600 to 800 Hz and an amplitude of 0.3 to 0.5 mm. In the case of a resonator of the type shown in FIG. **2**, with a blade 20 mm long and 0.2 mm thick and crystals 0–125 mm thick and about 4 mm long, the free end of the blade oscillates at a frequency of 400 to 600 Hz and an amplitude of 0.4 to 0.6 mm. The oscillation frequencies measured at the free end of a blade some 35 mm long having 5 to 6 mm long crystals secured to opposite sides lay between 200 and 300 Hz and the amplitudes observed were up to 1 mm. In all cases, the frequency of the resonator circuit and thus of the crystals was over 1,000 Hz.

The preferred length for the blades is comprised between 12 and 25 mm, while that of the crystals secured near the clamping point is between 20 and 25 percent of the length of the blades, so that the freely oscillating region of the blade beyond the crystal is at least about 50 percent of its overall length.

What is claimed is:

1. An electric resonator, in particular for driving timepieces, comprising a resonator circuit comprising a transistor having an emitter-collector circuit and a base-emitter circuit, a first crystal oscillator in the emitter-collector circuit, and a second crystal oscillator in the base-emitter circuit, means mechanically coupling the first and second crystals for the transmission of mechanical oscillations of one or the other, and a flexible blade having a free end and being clamped to a holder, in which at least said first crystal is secured to said blade adjacent the point of clamping the blade to the holder, and the length of the blade is greater than the largest dimension of said first crystal such that said free end oscillates at a sub-harmonic frequency of the resonant frequency of said resonator circuit.

2. A resonator as claimed in claim **1**, in which said first and second crystals are secured to opposite sides of said flexible blade.

3. A resonator as claimed in claim **1**, in which the first and second crystals are secured to first and second flexible blades clamped at a point to a common holder.

4. A resonator as claimed in claim **1**, in which the free end of said blades or one of said blades carries a transmission member driving a gear wheel.

5. A resonator as claimed in claim **1**, in which a further flexible blade is secured to said holder, said holder forming means for mechanically coupling said flexible blades for the transmission of mechanical oscillations of one to the other, said further flexible blade having a free end carrying a transmission member driving a gear wheel.

6. A resonator as claimed in claim **1**, in which the free end of a crystal-carrying blade has at least one longitudinal slit terminating away from the point at which the crystal is secured thereto.

7. A resonator as claimed in claim **1**, in which the dimensions of each crystal-carrying blade and crystal are such that the free end of the blade oscillates at a frequency of below 1,000 Hz and with an amplitude of at least 0.1 mm, the length of the blade being comprised between 12 and 25 mm, the largest dimension of the crystal being comprised between 20 and 25 percent of the length of the blade, and the length from the free end of the blade to the point where the crystal is secured is at least 50 percent the length of the blade.

8. A resonator as claimed in claim **1**, in which the blade is made of a material having a low temperature coefficient.

9. A resonator as claimed in claim **1**, in which each blade is secured to the holder by means of screws.

10. A resonator as claimed in claim **1**, in which a coil, and optionally a diode electrically connected in series to the coil, is connected in said collector-emitter circuit in parallel to the first crystal.

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