MECHANICAL RESONATOR OF ROTATION

Filed June 14, 1968 4 Sheets-Sheet 1

FIG.1

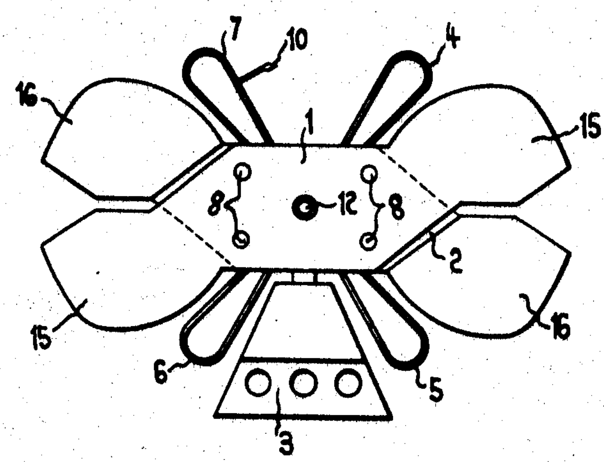

FIG.2

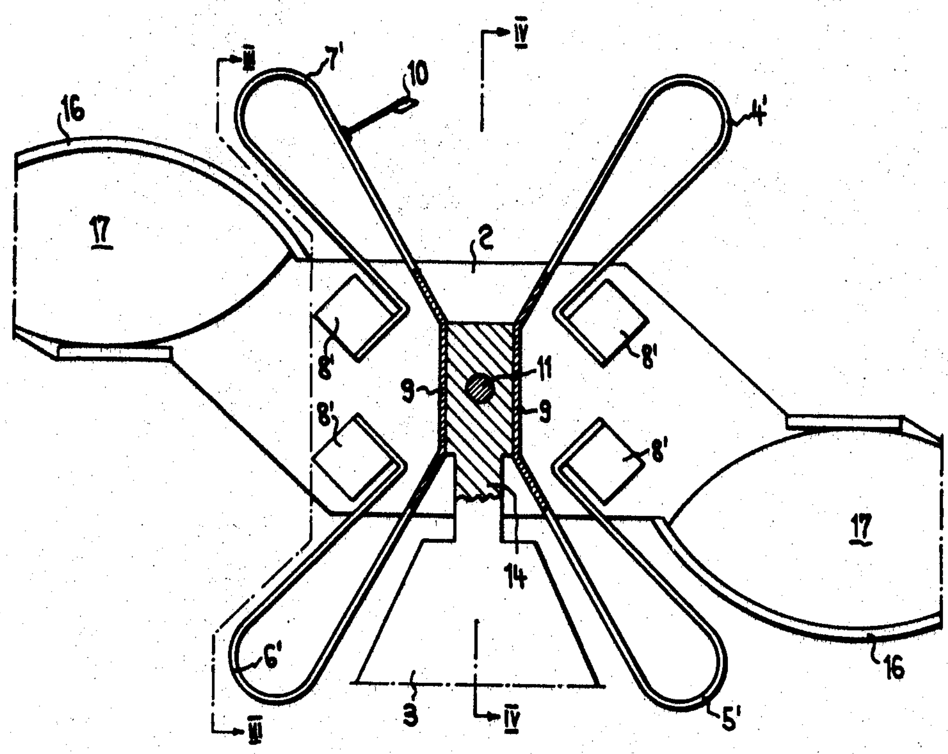

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FIG. 3

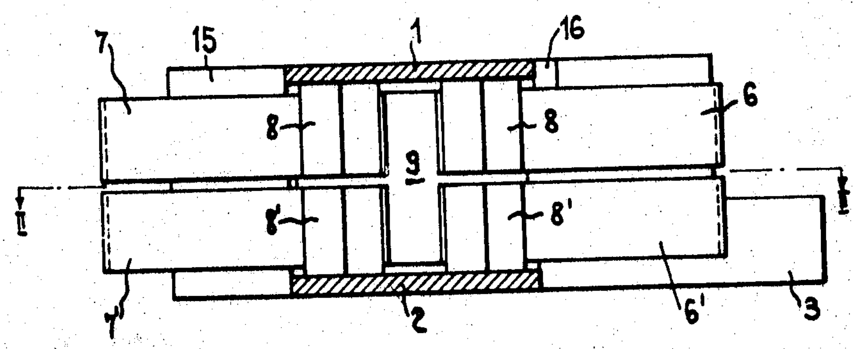

FIG. 4

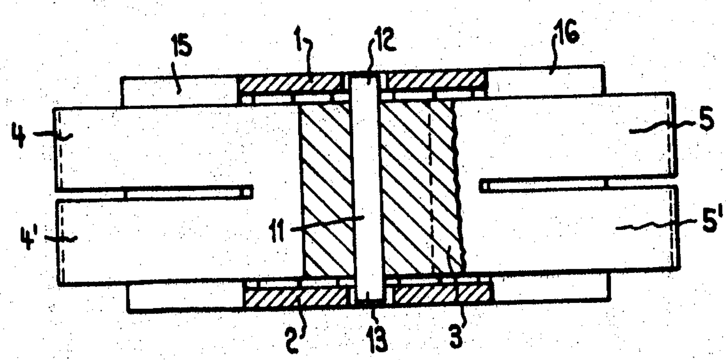

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FIG.5

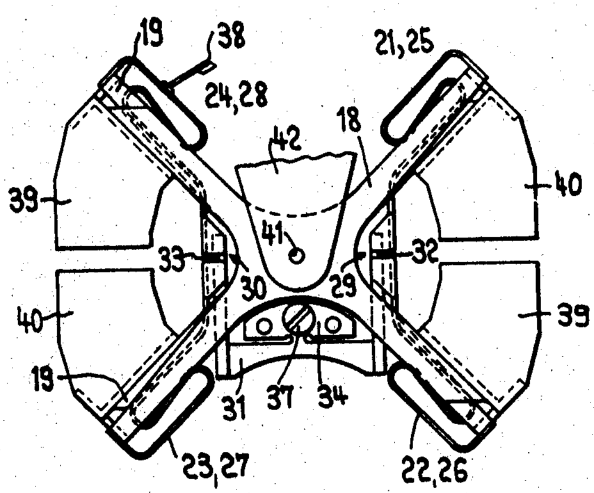

FIG.6

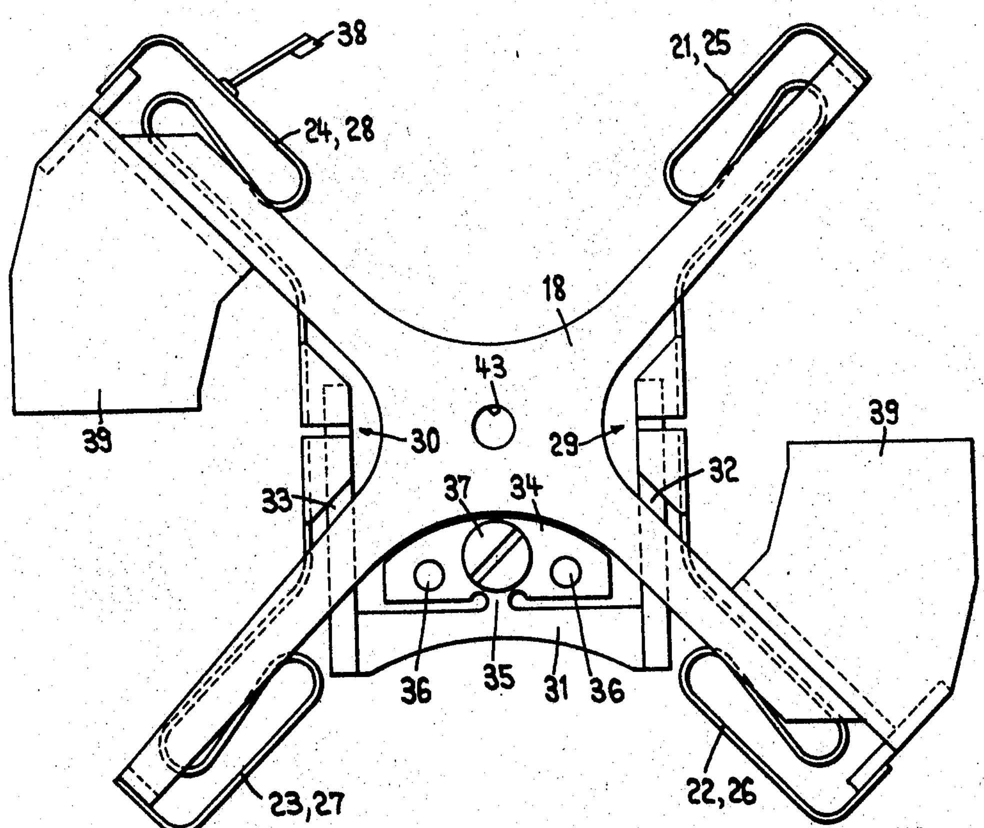

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FIG. 7

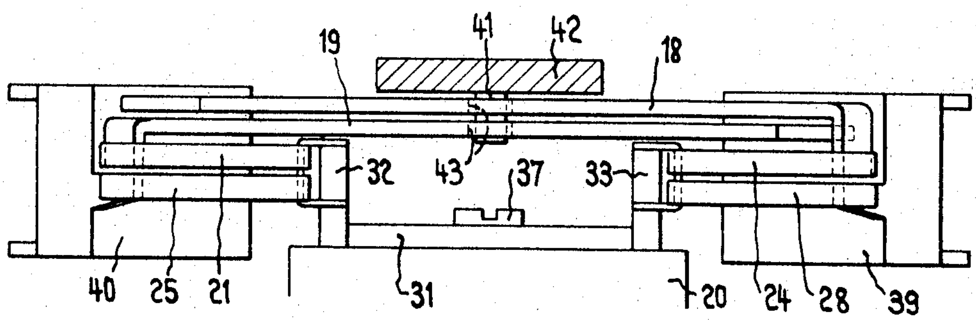
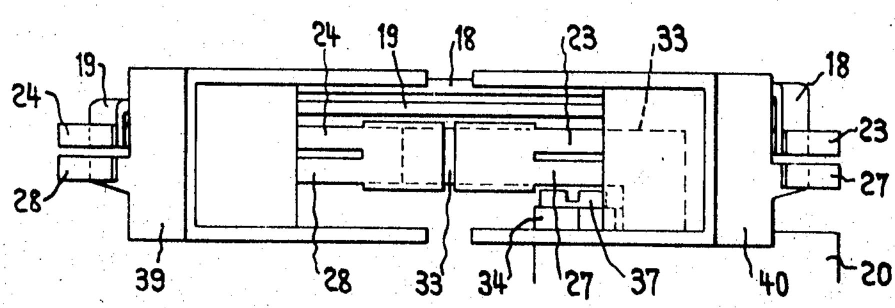


FIG. 8



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MECHANICAL RESONATOR OF ROTATION

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Int. Cl. F16h *27/02;* G04b *15/00*
U.S. Cl. 74—142 17 Claims

ABSTRACT OF THE DISCLOSURE

A timepiece movement includes an oscillatory mass having an axis of symmetry and a spring system supporting the mass for oscillation preferentially about such axis of symmetry. The spring system includes a number of leaf springs each secured at one end to a support and at their other ends to the mass with the widths of the springs lying parallel to the axis of symmetry and with the springs containing looped portions such that essentially radial arm portions thereof lie in closely spaced relation. These relations minimize displacements of the mass axially of the axis of symmetry and radially of such axis while allowing oscillations about the axis.

The present invention relates to a mechanical resonator of rotation.

Several types of mechanical resonators are known, the most common of which is the tuning fork. The latter has two drawbacks in its application as a time base of a wristwatch for example:

The lower symmetry order of the single tuning fork gives to the latter a relatively important effect of position in the field of gravity. The frequency of a tuning fork is higher when its branches are oriented towards the bottom than in the reverse direction, the forces due to gravity being added to the elastic return-forces;

The tuning fork is energizable by a lateral shock or a strong trepidation and this more especially as its frequency is lower. These outer effects cause, therefore, a perturbation of the rate.

Both above-mentioned effects are attenuated when the frequency is increased, so that the single tuning fork is practically nonusable as a time-base of a good wristwatch if its frequency is lower than 300 Hz. A lower frequency would, however, have several important advantages, specially a smaller consumption of current and a less delicate system for the transmission of the movement. The higher symmetry order which is found for instance in the double tuning fork or "H-tuning fork" and in other types of oscillators eliminates the effect of position, but not the effect of shock. In order to eliminate the latter, it is necessary to use a resonator of rotation, the most known example of which is the combined balance and hairspring.

A resonator compelled to perform a circular oscillation about an axis with respect to which it has an axial symmetry, cannot, as a rule, be energized or perturbed by a nondestructive shock. This is an exclusive privilege which, in combination with the absence of an effect of position if a dynamic balance is provided for, permits to operate the resonator of rotation at a relatively low frequency, for instance 180 Hz., which gives it the above-mentioned advantages.

Several resonators of rotation with audio-frequency are already known in the art. Thus, in a known construction (Swiss Pat. No. 367,443), a cruciform elastic structure permits oscillations of rotation by an important component of torsion, whereas it opposes a high rigidity to the undesired displacements of translation. However, it is not possible to give to this known structure the size desirable in the small space available within a wristwatch; therefore, the construction is susceptible to shocks which may provoke an overstepping of the elastic limits and accordingly a permanent frequency departure before the intervention of limiting stops.

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An ideal elastic structure for a resonator of rotation should permit:

The isochronism of the oscillations up to an amplitude sufficient for ensuring an excellent efficiency of the transducer and a sufficient virtual power at a relatively low frequency, for instance of 180 Hz.;

The presence of springs of a maximum active volume and having a shape adapted to the very confined space available in a wristwatch and to the presence of a transducer with high efficiency;

The possibility of a simple execution, at a competitive price.

The present invention aims at satisfying these conditions. It relates to a mechanical resonator of rotation, comprising at least one body mounted on a support in overhung position to perform circular oscillations around an axis of symmetry under the action of a device adapted to maintain the oscillations of said body, said resonator being characterized in that said body is mounted on said support by means of a plurality of springs the active portion of which, situated between a first connection with the body and a second connection with the support, has the shape of a cylindrical surface with generating lines parallel to the axis of oscillation of the resonator and retains this character during the elastic deformation generated by the circular oscillation, the length and the width of the active portion of the springs lying on the cylindrical surface, whereas the thickness thereof is perpendicular thereto, and that the developed length of said active portion is greater than the distance between its ends, so as to generate practically only oscillations of pure flexion and to increase as much as possible the active volume of the springs.

In the broad sense used in geometry, a "cylinder" is a ruled surface with parallel generating lines, of which the cylinder of revolution is only a particular example.

The accompanying drawings illustrate, by way of example, two embodiments of the invention.

FIG. 1 is a plan view of the first embodiment.

FIG. 2 is a cross-sectional view thereof, at an enlarged scale, along the line II—II in FIG. 3.

FIG. 3 is a cross-sectional view thereof, along the line III—III in FIG. 2.

FIG. 4 is a cross-sectional view thereof, along the line IV—IV in FIG. 2.

FIG. 5 is a plan view of the second embodiment.

FIG. 6 is a plan view thereof at an enlarged scale, the lower body being removed.

FIG. 7 is a side view thereof, partially in section, taken from the top in FIG. 5, at the same scale as FIG. 6.

FIG. 8 is a side view thereof, taken from the left in FIG. 5, at the same scale as FIG. 6.

The resonator of rotation illustrated in FIGS. 1 to 4 includes two oscillating bodies or heads **1** and **2** mounted on a central support **3** in overhung position to perform circular oscillations around an axis of symmetry. The body **1** is mounted on the support **3** by means of four springs **4** to **7** and the body **2** by means of four springs **4′** to **7′**. FIG. 2 shows how the springs **4′** to **7′** are connected with the body **2**; the latter carries four studs **8′** of square cross section, on which the springs are soldered after a rigid-angle bend in such a way that the soldered joints are acted upon only by tangential forces. In the same way, the springs **4** to **7** are connected with the body **1**, by means of studs **8** of which only the other end, of circular section, is seen in FIG. 1. Each of the eight springs has the shape of a tape or band having a constant thickness and a constant width and comprises substantially two plane portions, extending radially with respect to the axis of oscillation and connected with a circular cylindrical portion with generating lines parallel to the axis of oscillation. It will thus be seen that the active portion of the springs has the shape of a cylindrical surface (in the broad above-mentioned sense) with generating lines parallel to the axis of oscillation of the resonator, the length and the width of the active portion of the springs lying on the cylindrical surface, whereas their thickness is perpendicular thereto. In addition, the developed length of said active portion is greater than the distance between its ends, as this is clearly seen in FIG. 2. The springs of the same sustaining system are obtained in pairs from the same piece of material, i.e., here the springs **4** and **5**, on the one hand, **6** and **7**, on the other hand. The connection thereof with the central support **3** is ensured by a soldering of their common zone **9** (FIG. 2). A common elastic portion belongs to the sustaining springs of one of the bodies and to the sustaining springs of the other body, taken in pairs, so as to produce a dynamic coupling of both bodies. Thus, as seen in FIG. 4, the springs **4** and **4'**, respectively **5** and **5'**, have a common elastic portion in the vicinity of their soldering to the central support **3**. Due to this fact, the eight springs consist only of two separate pieces. The four springs **4**, **4'**, **5**, **5'** are, indeed, made from a single piece by stamping and bending; the same may be said for the four springs **6**, **6'**, **7**, **7'**.

One of the sustaining springs, in the example described the spring **7'**, carries an impulse pawl **10** adapted to cooperate with a ratchet wheel (not illustrated), in order to convert the oscillatory motion into a unidirectional movement of rotation. This arragement permits transmitting to the said pawl **10** only a fraction of the parasitic movements of the oscillating heads **1** and **2** produced by shocks and trepidations.

FIG. 3 illustrates the symmetry of the spring assembly of the resonator with respect to the axis II—II, which guarantees the dynamic balancing and the absence of any effect of position.

A rod **11** secured to the support **3** ends in two pivots **12** and **13** engaging with play bores of the heads **1** and **2**, respectively (FIG. 4). These pivots limit any accidental displacement of the heads **1** and **2**, without stopping the circular oscillation of said heads. In the absence of shock, the pivots **12** and **13** are not in contact with the oscillating heads **1** and **2**, so that no friction occurs.

As shown specially in FIG. 2, the support **3** has an arm **14** of reduced section, which has therefore a certain elasticity.

The head or body **1** has two lugs **15**, and in the same way the head or body **2** has two lugs **16**. In each of said lugs is arranged a permanent magnet **17** (see FIG. 2), serving for maintaining the oscillations of the resonator by means of a known electromagnetic device.

The dynamic balancing of the resonator is realized when both heads **1** and **2** are caused to oscillate at a phase-displacement of the angle π, i.e., in phase opposition, so that any reaction on the support **3** is done away with and a very small damping of the oscillation is rendered possible.

The resonator as illustrated and described ensures a rational working of the springs and permits giving them maximum dimensions with respect to the available space, so that a better resistance to shocks is obtained. Owing to the radial portions of the sustaining springs, the translation of the oscillating heads **1** and **2** in the plane of oscillation implies a relatively high force, and a displacement of these heads in a direction perpendicular to the plane of oscillation also encounters a great resistance, because the springs are then solicited edgewise. On the contrary, the rotation of the oscillating heads **1** and **2** generates only solicitations of flexion with respect to the relatively small thickness of the springs. The latter mode of oscillation is therefore strongly preferential.

It is often interesting that the overall size of a mechanical resonator, consisting of a time-base for a wristwatch, is as large as possible in order to improve the efficiency and the resonance factor. In the case of a round watch, the maximum overall size is attained when the great axis of the resonator occupies a chord nearly equal to the diameter of the watch.

It is known that the elements of a timepiece are strongly concentrated in the vicinity of the centre of the movement, so that the latter should be maintained available or vacant over a certain radius and a certain height. The central region of a resonator of maximum amplitude must, therefore, be itself vacant.

The second embodiment of the invention (FIGS. 5 to 8) just relates to a mechanical resonator of rotation permitting accommodating elements of a watch in its central region. This resonator includes two bodies or oscillating heads **18** and **19** mounted on a central support **20** in overhung position to perform circular oscillations around an axis of symmetry. In the present case, the support **3** consists of the pillar plate of a watch. The bodies **18** and **19** are mounted on the support **20** by means of eight springs **21** to **28**, the four upper springs being denoted by the reference numerals **21** to **24** and the four lower springs by the reference numerals **25** to **28**. Each body is connected with the support by two upper springs and two lower springs. More conceretely speaking, the upper body **18** is connected with the support by the upper springs **21** and **23** and the lower springs **26** and **28**, whereas the lower body **19** is connected with the support by the upper springs **22** and **24** and the lower springs **25** and **27**. This arrangement is chosen here for practical reasons, but it has a general advantage, due to the fact that the springs of the same level work in pairs of phase opposition, which better balances the forces than if all of the upper springs were connected with the same body, in which case they shuold work in phase. The dynamic balancing would then necessitate a solicitation of torsion on the soldering joints connecting the springs with the support.

A first group of springs **21**, **22**, **25**, **26** is connected with the fixing centre **29**, whereas a second group of springs **23**, **24**, **27**, **28** is connected with the fixing centre **30**. The attachment of the springs to the fixing centres **29** and **30** is obtained by bending the widened end of the springs and electric solderings arranged in such a way that they are exposed only to tangential forces. The fixing centres **29** and **30** are situated at a certain distance from the axis of oscillation of the resonator and are connected with each other by a yoke-shaped elastic element **31**, comprising two perpendicular branches **32** and **33** on which are soldered the springs. The elastic element **31** is spaced apart from the axis of oscillation of the resonator, so that the central region of the resonator remains available over a certain height for receiving elements of the watch; its axis of symmetry is perpendicular to the great axis of the resonator. The elastic element **31** is itself elastically connected with a base portion **34** by the elastic tongue **35**. Only the base portion **34** is in contact with the pillar plate **20**, on which it is positioned by pins **36** and secured by a screw **37**. The elastic element **31** which connects both fixing centres **29** and **30** with each other contributes to linearize the constraints of oscillation, and therefore to render the frequency of oscillation independent of the amplitude (isochronism).

The spacing of the branches **32** and **33** of the elastic element **31** slightly influences the resonance frequency in such a way that it is possible to contemplate the correction of the thermic coefficient of frequency by a bimetallic structure of these branches.

The developed length of the springs **21** to **28** is relatively large with respect to the distance between both extreme connecting points of each of them, so as to avoid nonlinear elastic solicitations. In the embodiment shown, the springs **21** to **28** have the shape of a double hairpin, as clearly illustrated in FIGS. 5 and 6.

FIGS. 7 and 8 illustrate the details of structure of the elastic element **31**, with its branches **32** and **33**, and of the springs **21** to **28**. These springs are arranged in pairs. One of the springs, in the example described the spring **24**, carries an impulse pawl **38** adapted to cooperate with a ratchet wheel (not illustrated), in order to convert the oscillatory motion into a unidirectional movement of rotation.

As shown in FIGS. 5 and 6, each of the bodies **18** and **19** comprises a cruciform arm carrying two diametrically opposed transducerd elements **39**, **40**. Each of the transducer elements has a permanent magnet serving for maintaining the oscillations of the resonator by a known electromagnetic device.

A rod **41** carried by a stationary bridge **42** engages with play bores **43** of the heads **18** and **19**, in order to limit any accidental displacement of the heads **18** and **19**, without stopping the circular oscillation of said heads. In the absence of shocks, the rod **41** is not in contact with the oscillating heads **18** and **19**.

The dynamic balancing of the resonator is realized when both heads **18** and **19** are caused to oscillate at a phase displacement of the angle π, i.e., in phase opposition, so that any reaction on the suport **20** is done away with and a very small damping of the oscillation is rendered possible.

FIG. 7 shows how the cruciform arms of the bodies **18** and **19** are situated on the same side of the springs **21** to **28** in order to liberate at best the volume in the vicinity of the centre of oscillation, adapted to receive elements of the watch.

What is claimed is:

1. In a timepiece resonator, in combination,

an oscillatory mass having an axis of symmetry perpendicular to a predetermined plane,

a support,

spring means connecting said mass to said support for oscillation of the latter about a rotational axis substantially coinciding with said axis of symmetry, said spring means including a leaf spring having a width substantially greater than its thickness and arranged with its widthwise faces perpendicular to said predetermined plane, said leaf spring being secured at one end to said support and at its other end to said mass, said leaf spring including elongate arm portions extending generally radially with respect to said axis and in closely spaced opposition to each other in side-by-side relation in a direction normal to said axis whereby to resist both radial and axial displacement of said mass with respect to its rotational axis under shock loading conditions.

2. In a timepiece resonator, in combination,

an oscillatory mass having an axis of symmetry perpendicular to a predetermined plane,

a support, and

spring means connecting said mass to said support for oscillation of the mass about a rotational axis substantially coinciding with said axis of symmetry, said spring means including a plurality of strip-like leaf springs each having a width substantially greater than its thickness and each arranged with its widthwise faces perpendicular to said predetermined plane, each said leaf spring being secured at one end to said support and at its other end to said mass and each including closely spaced arm portions disposed essentially radially with respect to said axis of symmetry and in side-by-side relation in a direction normal to said axis the arm portions of the several leaf springs being symmetrically arranged about said axis of symmetry, and the length of each leaf spring being substantially greater than the distance between its point of connection to said support and its point of connection to said mass.

3. In the timepiece resonator as defined in claim **2** wherein said arm portions are joined by loops.

4. In the timepiece resonator as defined in claim **2** including a stop connected to said support, said mass having an enlarged opening at its axis of symmetry within which said stop is received with clearance, whereby positively to limit radial displacement of said mass under the influence of shock loading.

5. In the timepiece resonator as defined in claim **2** including a mounting base, and means joining said support to said base for elastic movement thereof about an axis parallel to but displaced from said axis of symmetry.

6. In the timepiece resonator as defined in claim **5** wherein said support is U-shaped presenting legs to the free ends of which said leaf springs are joined, said legs being resilient to allow movement of the free ends thereof toward and away from each other.

7. In the timepiece resonator as defined in claim **2** wherein the opposite ends of said leaf springs are bent into planes generally tangential with respect to radii passing through said axis of symmetry, means joining such opposite ends of the leaf springs respectively in face-to-face opposition to said support and said mass, whereby such means is subjected essentially only to shear incidental to inertia forces arising from the oscillations of said mass.

8. In the timepiece resonator as defined in claim **7** wherein such means is effected by solder.

9. In the timepiece resonator as defined in claim **2** wherein each leaf spring is of hairpin shape.

10. A resonator for timepieces comprising, in combination,

a generally flat oscillatory mass having an axis of symmetry perpendicular thereto,

a support,

a plurality of elongate leaf springs, each having an inner end portion fixed to said support with the various points of fixation being arranged symmetrically around said axis of symmetry, each leaf spring having an outer end fixed to said mass with the various points of fixation between such outer ends and said mass being arranged symmetrically about said axis of symmetry, each leaf spring being of a length substantially greater than the radial spacing between its inner and outer ends and each presenting a plurality of closely spaced arms disposed essentially radially with respect to said axis of symmetry, and in side-by-side opposed relation in a direction normal to said axis and each leaf spring having its widthwise dimension disposed parallel to said axis of symmetry so as to be perpendicular to the plane of said mass, whereby to minimize axial and radial displacement of said mass with respect to said axis of symmetry while preferentially allowing oscillation thereof about said axis of symmetry.

11. In the timepiece resonator as defined in claim **2** wherein there are four leaf springs arranged in integral pairs, the said one ends of one pair being integrally joined and the said one ends of the other pair being integrally joined.

12. A resonator for timepieces comprising, in combination,

a pair of oscillating masses, each of generally flat form and each having an axis of symmetry perpendicular thereto, said masses being disposed in side-by-side relation with their axes of symmetry substantially coincidental,

a support, and

a plurality of leaf springs extending between said support and

said masses, each leaf spring having its widthwise faces parallel to said axes of symmetry whereby to resist displacements of said masses axially of said axes of symmetry under shock loading conditions, and each leaf spring having a reversely bent intermediate portion presenting closely spaced essentially radial arm portions in side-by-side opposed relation in a direction normal to said axes whereby to resist displacements of said masses radially of said axes of symmetry under shock loading conditions.

13. A resonator as defined in claim **12** wherein there are four pairs of leaf springs, each pair being disposed in side-by-side relation and having those portions thereof adjacent said support integrally interconnected.

14. A resonator as defined in claim **13** wherein two of said pairs of leaf springs are integrally joined at those portions adjacent said support.

15. A resonator as defined in claim **12** wherein said support comprises a flat plate disposed below said masses and to one side of said axes of symmetry, said support including a yoke presenting generally parallel legs projecting toward but straddling said axes of symmetry and to the free ends of which said leaf springs are attached to provide a space between said legs and below said masses within which other timepiece elements may be mounted.

16. A resonator of the character described comprising, in combination,

a generally flat mass having an axis of symmetry perpendicular thereto,

a support for said mass,

a spring system carried by said support for rotationally centering said mass for easy movement about its axis of symmetry while resisting axial and radial displacements of said mass with respect to its axis of symmetry which may be due to shock loading of the resonator, and

means symmetrically arranged on said mass remote from said axis for imparting impulses thereto tending to rotate said mass about its axis of symmetry in opposition to said spring system,

said spring system comprising a plurality of elongate leaf springs extending generally radially of said axis outwardly from said support to said mass, said leaf springs having their widthwise faces parallel to said axis and having reverse looped portions presenting closely spaced essentially radial arm positions in side-by-side opposed relation in a direction normal to said axis to increase the effective lengths of said leaf springs while effecting the resistance to said axial and radial displacement of the mass.

17. The resonator as defined in claim **16** wherein said mass is provided with an enlarged opening at its axis of symmetry, and stop means projecting into said opening, with clearance, positively to limit said axial and radial displacements which may be imparted to said mass under shock loading conditions.

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WESLEY S. RATLIFF, JR., Primary Examiner

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