United States Patent

[11] 3,582,698

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[54] **RESONATOR WITH COUNTERROTATING RIGID PARTS**
4 Claims, 6 Drawing Figs.

[52] **U.S. Cl.** **310/8.2,** 310/8.5, 333/72
[51] **Int. Cl.** **H01v 7/00**
[50] **Field of Search** 310/8.2, 8.3, 8.5, 8.1, 25, 36; 333/72, 30, 71

[56] **References Cited**

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Assistant Examiner—B. A. Reynolds
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ABSTRACT: A resonator comprising a plurality of rigid pivotable members are interconnected by a flexible member which is arranged to induce counterrotary movement of the rigid members upon driving of one of the members. In order to provide a resonator having a relatively low resonant frequency, the flexible member is relatively long and is connected to the rigid members on opposite sides of the nodal axes thereof.

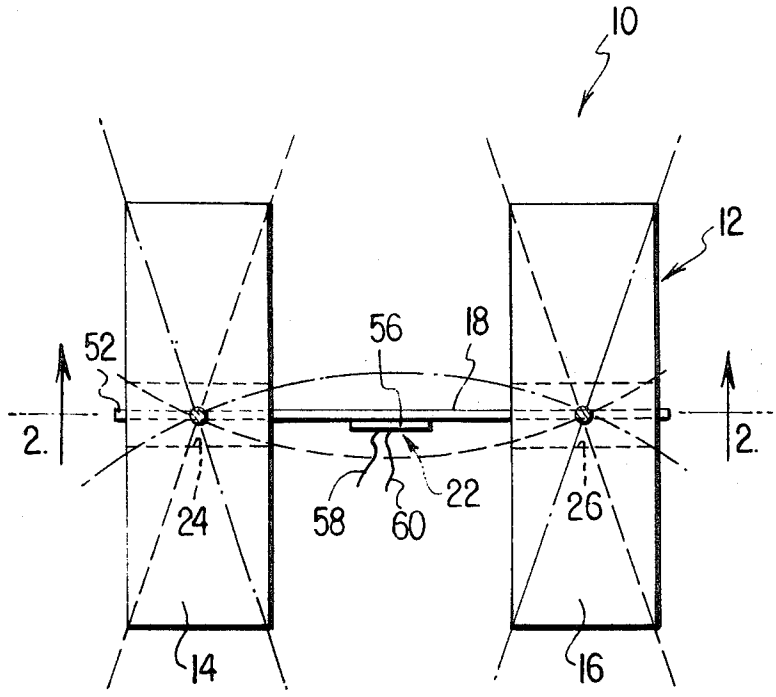


FIG. 1

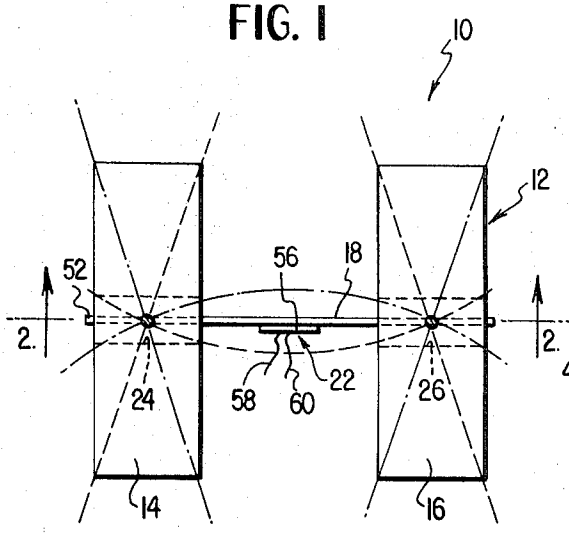


FIG. 2

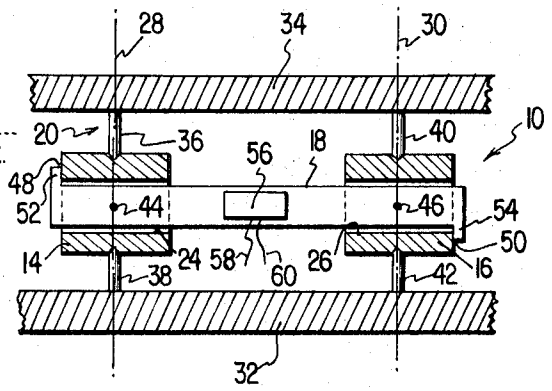


FIG. 3

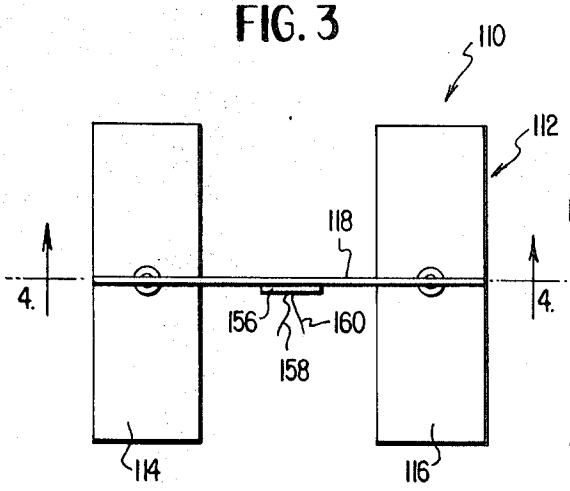
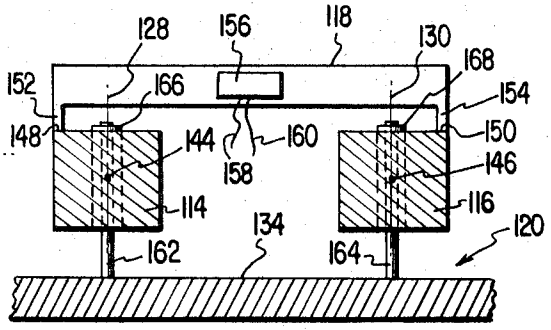


FIG. 4



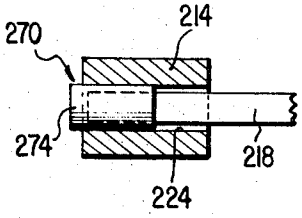


FIG. 6

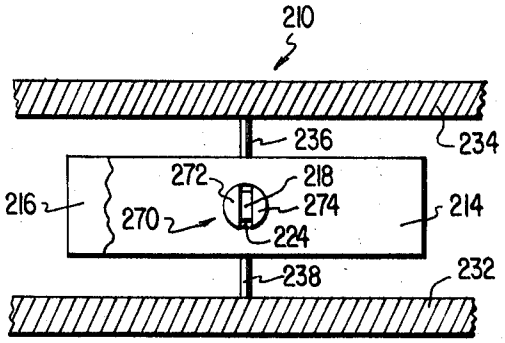


FIG. 5

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RESONATOR WITH COUNTERROTATING RIGID PARTS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is related to application Ser. No. 565,430 entitled RESONATOR TOGETHER WITH METHOD AND MEANS FOR VARYING THE FREQUENCY THEREOF, filed July 15, 1966, and application Ser. No. 714,221 entitled RESONATOR, now U.S. Pat. No. 3,453,464, filed Mar. 19, 1968.

BACKGROUND OF THE INVENTION

This invention relates to resonators and filters of the electromechanical type. An electromechanical resonator is disclosed in *Electronics Magazine*, Oct. 2, 1967, pages 99–106 which comprises a pair of rigid members arranged to pivot or rotate about the nodal axis thereof. The rigid members are interconnected by a bodily flexible member arranged to induce counterrotary movement between the rigid parts. The device disclosed in this publication is likewise disclosed and claimed in application Ser. No. 565,430 and is generally H-shaped in configuration with the flexible part or web being substantially smaller than the rigid parts.

It has been found desirable to provide a resonator of this general type which is adapted for low-frequency operation. For example, it may be desirable to provide a 60-cycle resonator. One mode of accomplishing this desideratum is to make the flexible part or web of substantially greater length. It may be readily appreciated that the third part or web of the resonator disclosed in the aforementioned application and publication may be made of any desirable length. It will be apparent that the device a assumes substantially greater external dimensions and therefore sacrifices compactness to some extent when the web is increased in length. One approach for increasing the overall dimension of the web without increasing the external dimension of the resonator is disclosed in application Ser. No. 714,221 wherein the web is diagonally arranged between opposite ends of the rigid parts. One characteristic of the device disclosed in this application is that the web is quite flexible and is driven with very small forces. Consequently, electromagnets and very thin piezoelectric wafers are most conveniently used to drive this type of resonator. Some difficulty has been encountered in providing sufficiently thin piezoelectric wafers for this type device.

SUMMARY OF THE INVENTION

In order to provide a resonator comprising counterrotating rigid parts having a relatively long web, the web or flexible part is secured to the rigid members in the plane defined by the nodal axes with both of the nodal axes being disposed between the connections of the web and the rigid parts.

It is accordingly an object of the invention to provide a low-frequency compact resonator comprising a plurality of bodily rigid members arranged to rotate about the nodal axes thereof.

Another object of the invention is to provide a compact resonator capable of low-frequency operation comprising first and second bodily rigid members and a third bodily flexible member arranged to induce counterrotary movement of the first and second members upon driving of one of the members.

Another object of the invention is to provide a resonator of increased quality or selectivity which is capable of low-frequency operation without changing the external dimensions of the device.

Still another object of the invention is to provide a resonator having high Q and large movements of the moving parts.

Further objects, advantages and important features of the invention will be apparent from a study of the specification following taken with the drawing which together describe and disclose preferred embodiments of the invention in what is now considered and believed to be the best mode of practicing the principles thereof. Still other embodiments, modifications or equivalents may be apparent to those having the benefit of the teachings herein and such other embodiments, modifications or equivalents are intended to be reserved especially as they fall in the scope and breadth of the subjoined claims.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a top plan view of one embodiment of the invention, certain parts being omitted for purposes of clarity;

FIG. 2 is a transverse cross-sectional view of the embodiment of FIG. 1 taken substantially along line 2–2 thereof as viewed in the direction indicated by the arrows;

FIG. 3 is a top plan view of another embodiment of the invention;

FIG. 4 is a transverse cross-sectional view of the embodiment of FIG. 3 taken substantially along line 4–4 thereof as viewed in the direction indicated by the arrows;

FIG. 5 is a side elevational view of another embodiment of the invention illustrating a different type of connection between the flexible web and the rigid parts;

FIG. 6 is a partial sectional view of the embodiment of FIG. 5 illustrating the connection between the flexible part and the rigid part.

DETAILED DESCRIPTION OF THE EMBODIMENTS

Reference is made to FIGS. 1 and 2 wherein there is shown a resonator **10** having as major components an oscillatible structure **12** comprised of first and second rigid parts **14, 16** and a flexible part **18**, support means **20** and means **22** for energizing the oscillatible structure **12**.

The parts **14, 16** may be described as bodily rigid or rigid by which is meant that the parts **14, 16** are unflexing at a resonant frequency of the resonator **10** a although the parts **14, 16** may flex at higher frequencies. The parts **14, 16** are illustrated as rectangular in configuration but may be of any suitable geometric shape, such as cylinders, externally threaded cylinders, externally threaded tubes, internally threaded tubes, tubes, internally and externally threaded tubes, dumbbells, cones, D-shaped segments or the like.

Although it is preferred that the parts **14, 16** be of the same geometric shape for convenience of manufacture, such is not necessary. Since the quality or Q of this type resonator is highest when the parts **14, 16** have equal mass moments of inertia, it is preferred that the mass moments of inertia be sufficiently close to provide a resonator of the quality desired for a given application. The mass moments of inertia of the parts **14, 16** may be adjusted by adjustably mounting an additional weight on the exterior of the rigid members **14, 16**, by adjustably mounting an additional weight in an internal passageway in the parts **14, 16** or by a combination of both. As will be realized by those skilled in the art, the change of mass moment of inertia will produce a change in the resonant frequency of the resonator **10**. The first and second parts **14, 16** are provided with an aperture or passageway **24, 26** extending through the nodal axis **28, 30** respectively of the parts **14, 16**. The purpose of the passageways **24, 26** will become apparent as this description proceeds.

The support means **20** comprises a base **32** and a spaced plate **34**. A set of aligned conical bearings **36, 38** and **40, 42** is provided for the rigid parts **14, 16** and enables the parts **14, 16** to rotate about the respective nodal axis **28, 30**. The nodal axes **28, 30** substantially intersect the center of gravity **44, 46** of the rigid parts **14, 16**. It will be apparent that any suitable bearing construction may be used.

The third part **18** is arranged to induce counterrotary movement of the first and second parts **14, 16** and is affixed thereto at first and second locations **48, 50** respectively. The third part **18** may be described as bodily flexible or flexible by which is meant that the part **18** is flexible at a resonant frequency of the parts **14, 16** even though it may be rigid at lower frequencies. The third part **18** extends through the passageways **24, 26** and may be provided with projections **52, 54** at the ends thereof to facilitate securement to the parts **14 16**. The projections **52, 54** may be welded, soldered, glued or otherwise secured to the parts **14, 16** in any suitable manner.

It will be noted that the nodal axes **28, 30** define a plane in which the first and second locations **48, 50** substantially reside. It will also be seen that the nodal axes **28, 30** are located between the first and second locations **48. 50.** This arrangement provides the longest web commensurate with transverse dimensions of the resonator **10.** It will be apparent to those skilled in the art that the locations **48, 50** may reside between the nodal axes **28, 30** and the external edge of the rigid parts **14, 16.**

The energizing means **22** preferably comprises a piezoelectric wafer **56** energized by a pair of wires **58, 60** in a conventional manner. When a voltage of given polarity is applied to the piezoelectric element **56,** the element **56** expands to move the flexible part **18** into the upwardly concave configuration shown in dashed lines in FIG. **1.** Because of the connection between the part **18** and the parts **14, 16,** the parts **14, 16** are counterrotated about the nodal axes **28, 30** into the upwardly converging attitude shown in dashed lines in FIG. **1.** When the polarity of the signal imparted to the piezoelectric element **56** is reversed, the element **56** contracts to move the flexible part **18** into the upwardly concave configuration shown in FIG. **1** as a dashed-dotted line. Because of the connections between the part **18** and the rigid parts **14, 16,** the rigid parts **14, 16** counterrotate about the nodal axes **28, 30** into the upwardly divergent attitude shown in FIG. **1** also in dashed-dotted lines. It is apparent that the apertures **24,26** allow flexing of part **18** without physically contacting either of the parts **14, 16.**

Because the web **18** is quite long, it can undergo substantial deflections. Consequently, a relatively flexible web produces a resonator of relatively low-frequency. Such a resonator rotates the parts **14, 16** a substantially greater arc than the corresponding parts disclosed in the aforementioned publication and the length of movement of the rigid parts **14, 16** is increased accordingly. Furthermore, there is no loss of Q even when the device is operating with relatively large movement of the parts **14, 16.** The basic reason is that the distance between the location **48, 50** is greatest when the web **18** is straight. When the web **18** bends, the natural tendency of the ends thereof is to come together slightly. Since the locations **48, 50** come closer together as the parts **14, 16** move away from the at-rest position, this natural tendency of the web **18** is accommodated with minimum stretching of the web. It will be apparent that these characteristics may prove advantageous in various applications for electromechanical resonators.

A major advantage of this device as compared to the embodiments shown in application Ser. No. 714,221 is that the web **18** can be substantially stiffer. This advantage is more important when a piezoelectric drive is used for the resonator as contrasted to an electromagnetic or other type drive. It is characteristic of piezoelectric drives that they prefer to operate against a relatively stiff member rather than a relatively flexible member for better mechanical impedance matching. With a relatively stiff web **18** as provided by this invention, the mechanical impedance of a piezoelectric wafer can be readily matched against the mechanical impedance of the web **18.**

Attention is now directed to FIGS. **3** and **4** where in there is shown a resonator **110** constituting another embodiment of the invention. For purposes of brevity, analogous reference characters are used to indicate analogous elements, most of which will not be specifically discussed. As will be apparent, the major differences between the embodiment of FIGS. **1** and **2** and the embodiment of FIGS. **3** and **4** resides in the location of the flexible part **118** and the resultant changes necessitated in the support means **120.**

It will be seen that the rigid parts **114, 116** reside in a plane generally parallel to the base **132.** Rather than extending through the rigid parts **114, 116** as in the embodiment of FIGS. **1** and **2,** the third part **118** is disposed in a second plane spaced from the plane defined by the parts **114, 116.** The third part **118** is provided with projections **152, 154** which are secured to the parts **114, 116** at locations **148, 150** on opposite sides of the nodal axes **128, 130.**

Since it is preferred to have the third part **118** as uncomplicated as possible, the support means **120** extends from only one side of the resonator **110.** Consequently, the support means **120** comprises pivot pins **162, 164** encased in a resilient sleeve **166, 168.** It will be seen that the pivot pins **162, 164** and the resilient sleeves **166, 168** enable the rigid parts **114, 116** to rotate about the nodal axes **128, 130.** It will also be apparent that the third part **118** is arranged to induce counterrotary movement of the rigid parts **114, 116** in a manner substantially identical to that discussed previously.

Attention is now directed to FIGS. **5** and **6** wherein there is shown a resonator **210** constituting another embodiment of the invention. For purposes of brevity, analogous reference characters are used to indicate analogous elements, most of which will not be specifically discussed. The major difference between the embodiment of FIGS. **5** and **6** and the embodiment of FIGS. **1** and **2** resides in the manner of connecting the web **218** to the rigid parts **214, 216.** Rather than welding, soldering or glueing the flexible part **218** to the rigid parts **214, 216,** a split-bushing arrangement **270** is provided. The split-bushing arrangement **270** comprises a pair of substantially identical bushing halves **272, 274** which receive the flexible web **218** therebetween. The bushing halves **272, 274** and the third part **218** are press fit or shrink fit into the passageway **224** to provide a force-transmitting connection between the web **218** and the rigid part **214.**

The resonator **210** is provided with suitable energizing means, preferably piezoelectric, but not limited thereto, for driving the rigid parts **214, 216** in the same manner as discussed previously with respect to the resonators **10, 110.**

While the invention has been shown, illustrated and described in terms of embodiments or modifications which it has assumed in practice, the scope of the invention should not be deemed to be limited by the precise embodiments or modifications herein shown or disclosed.

I claim:

1. A resonator comprising

first and second parts unflexing at a resonant frequency of the resonator;

means supporting the first and second parts in a first plane to enable the parts to rotate about the nodal axes thereof, the nodal axes substantially intersecting the respective centers of gravity of the parts and defining a second plane perpendicular to the first plane;

a third part outside the first plane, flexible at a resonant frequency, connected to the first and second parts at first and second locations to induce counterrotary movement of the first and second parts upon driving of one of the parts, the first and second locations being substantially in the second plane with both nodal axes being between the first and second locations; and

means for driving one of the parts.

2. The resonator of claim **1** wherein the first and second locations are disposed on the other edges of the first and second parts respectively.

3. The resonator of claim **1** wherein the first and second parts have substantially equal mass moments of inertia.

4. The resonator of claim **1** wherein the first and second locations are equidistant from the nodal axes.