United States Patent

Takaku et al.

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[54] PIEZOELECTRIC CERAMIC FILTER

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[73] Assignee: **Toko, Inc.,** Tokyo, Japan

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.**.....**333/72,** 310/9.7

[51] **Int. Cl.**.....**H03h 7/10**

[58] **Field of Search**.....333/72, 10; 310/9.7, 9.8

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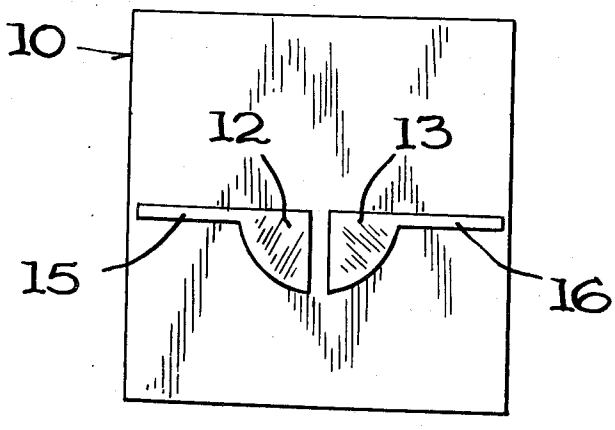
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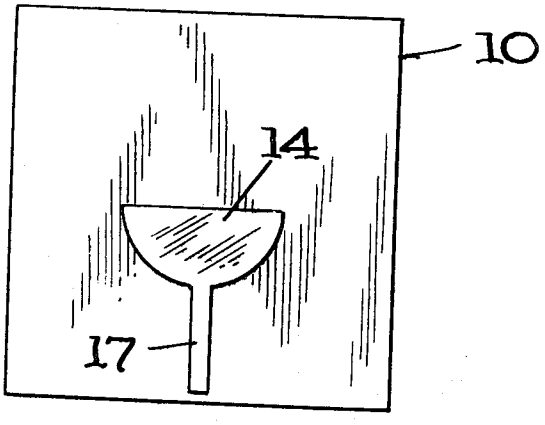
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Assistant Examiner—Saxfield Chatmon, Jr.
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[57] **ABSTRACT**

An improved piezoelectric ceramic filter for use in a frequency range above 1 MHz., which uses the thickness expansion or thickness shear mode of the vibration of a thin ceramic plate having opposed surface electrodes, and having conductor leads from the electrodes disposed at right angles. The body of the filter is a thin ceramic platelike member. A divided active electrode comprising a pair of electrode sectors each having a relatively straight marginal side is mounted on one surface of said body in a manner whereby the marginal straight sides are spaced slightly apart in parallel. A ground electrode is mounted in at least partial peripheral alignment with said active electrode, but on the opposite surface of said body, and corresponds in area size and shape to at least a major portion of that of said active electrode. The active and ground electrodes have a common overlap area which is not in excess of an area whose linear dimension in one direction is one-half that of the other direction, and said area is preferably of a semicircular shape.

7 Claims, 10 Drawing Figures





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SHEET 1 OF 2

PRIOR ART

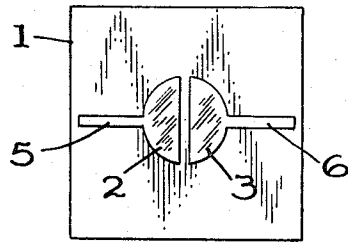


FIG. 1.

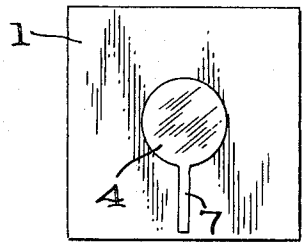


FIG. 2.

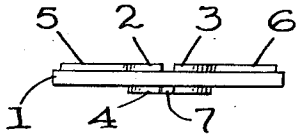


FIG. 3.

FIG. 4.

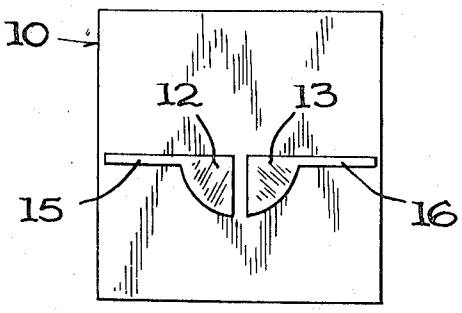


FIG. 5.

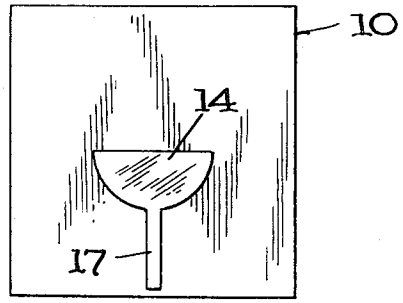


FIG. 6.

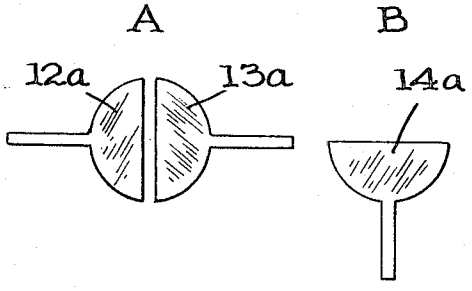
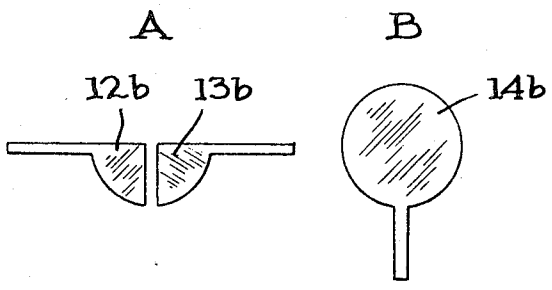


FIG. 7.



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FIG. 8.

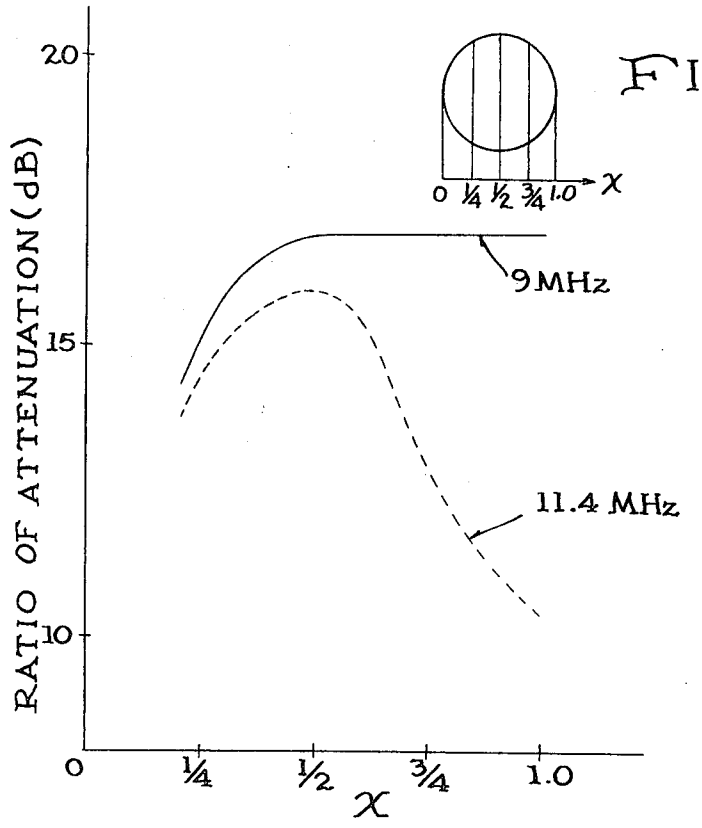


FIG. 8a.

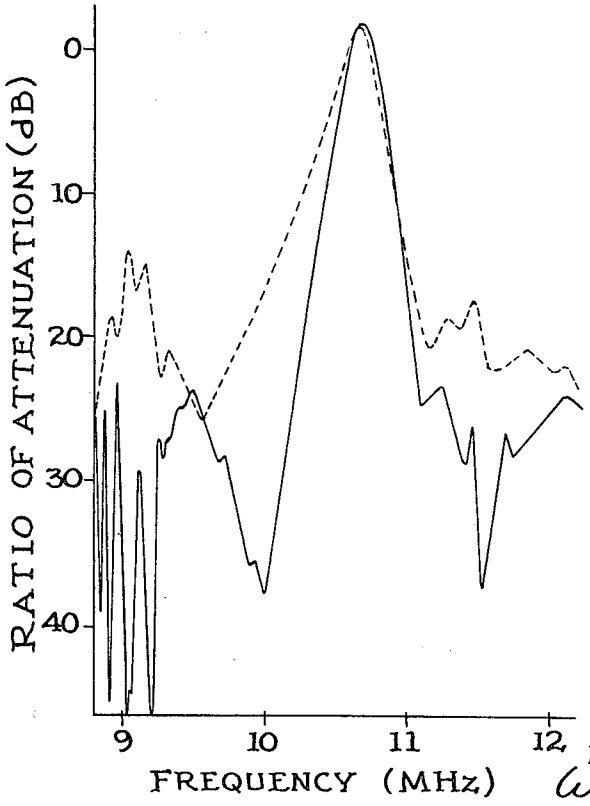


FIG. 9.

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PIEZOELECTRIC CERAMIC FILTER

The present invention relates to improvements in a divided electrode piezoelectric ceramic filter in which the attenuation characteristics depend on the thickness expansion or thickness shear mode in the ceramic composition, and in which a sharp attenuation characteristic is exhibited.

One of the principal objects of the present invention is to provide a new and improved divided electrode piezoelectric ceramic filter, and particularly to provide a divided electrode piezoelectric ceramic filter which stably exhibits a sharp filtering effect to attenuate spurious frequencies in a range, for example below about 9 MHz. or above 11.4 MHz., and at the same time to provide higher selectivity against unwanted responses.

Such a divided electrode piezoelectric ceramic filter of the present invention features a semicircular portion composed of and in which two active quadrant-shaped electrodes face a ground electrode through the ceramic plate therebetween on which they are mounted to achieve a superior attenuation characteristic over a range of more than 1 MHz., utilizing the thickness expansion or thickness shear mode within the semicircular portion.

In order to illustrate the salient features of the present invention in relation to the piezoelectric ceramic filters known in the prior art, attention is directed to the accompanying drawings which exemplify the chief characteristics of the improved piezoelectric ceramic filters disclosed herein.

FIG. 1 is a top plan view of a prior art piezoelectric ceramic filter;

FIG. 2 is a back or bottom plan view of the prior art filter of FIG. 1;

FIG. 3 is an elevation view of the assembled filter of FIGS. 1 and 2;

FIG. 4 is an enlarged top plan view of one improved divided electrode piezoelectric ceramic filter according to this invention;

FIG. 5 is a back or bottom plan view of the piezoelectric ceramic filter of FIG. 4;

FIGS. 6 and 7 in parts A thereof show combinations of the divided active electrodes, hereinafter referring to the electrodes at a potential higher than ground; and in parts B thereof show the corresponding ground electrode, respectively, of modified embodiments of the present invention;

FIGS. 8 and 8*a* show experimental comparative graphic results on the effect of varying the area encountered by the combined active electrodes and the ground electrode having the ceramic body therebetween, with respect to the magnitude of spurious response; and

FIG. 9 shows, in solid line, the graphic comparison of the attenuation characteristics exhibited by the piezoelectric ceramic filter of this invention as compared with that of said prior art device shown by a dashed line.

A typical prior art piezoelectric ceramic filter used at frequencies above 1 MHz. is shown in FIGS. 1–3, wherein two active electrodes 2 and 3 are provided on one surface of the piezoelectric ceramic plate 1. The plate 1 is shown preferably in the shape of a thin, rectangular plate, and said two active electrodes 2 and 3 are depicted as spaced apart semicircular sections which lie separately with the diametrical or base edges facing each other and designed to be connected for input or output, respectively, thereafter. The ground electrode 4, provided on the reverse surface of said ceramic plate 1, is shaped circularly to correspond in size with the combined sections of said two active electrodes 2 and 3. Furthermore, conductor leads 5 and 6 are connected with the two active electrodes 2 and 3, respectively, at diametrically opposite ends thereof, and at least one conductor lead 7 is connected with the ground electrode 4, said lead 7 being disposed at a right angle to the arrangement of said conductor leads 5 and 6. The above-mentioned electrodes are composed or may be attached to the ceramic plate 1 by means of plating, evaporation or screen-print operation.

One of the principal objects of the present invention is to provide a new and improved divided electrode piezoelectric ceramic filter, and particularly to provide a divided electrode piezoelectric ceramic filter which stably exhibits a sharp filtering effect to attenuate spurious frequencies in a range, for example as shown in FIG. 9, at about 9 MHz., and at about 11.4 MHz., and at the same time to provide higher selectivity against unwanted responses.

Such a divided electrode piezoelectric ceramic filter of the present invention features a semicircular portion composed of and in which two active quadrant-shaped electrodes 12 and 13 face a ground electrode 14 through the ceramic plate 1 therebetween, on which they are mounted to achieve superior attenuation characteristics over a range of more than 1 MHz., utilizing the thickness expansion or thickness shear mode within the semicircular portion.

In FIGS. 4 and 5, depicting the improved filter hereof, a piezoelectric ceramic thin, preferably rectangular shaped plate 10 serves as the main body and is provided with a pair of active electrodes 12 and 13 formed on one surface of said plate. Said electrodes 12 and 13 have the form of pie-shape quadrant sectors whose diverging radius sides form a right angle, respectively, and lie at a position of symmetry with a radius edge of each sector in parallel thereon, as shown in FIG. 4. The ground electrode 14, as provided on the opposite surface of said thin ceramic plate 10, is of semicircular shape corresponding in size to agree with the combined active electrode sections 12 and 13 at the peripheral circumference. Conductors 15, 16, and 17 are connected with the active electrodes 12 and 13, and to said ground electrode 14, respectively, in which the conductor 17 is positioned at a right angle to the arrangement of the two conductors 15 and 16 in a manner like that described for the prior art device of FIGS. 1–3.

FIGS. 6 and 7 show other combinations of modified arrangements of the active electrodes and the ground electrode in accordance with the invention.

FIG. 6 shows semicircular electrodes 12*a*, 13*a* and 14*a* composing, respectively, the two active electrodes and the ground electrode disposed in the same general pattern as in FIG. 5, except for the electrodes each being semicircular sectors. The diametrical edge of the ground electrode is disposed at a right angle in a bisecting manner relative to the corresponding parallel spaced edges of the active electrodes.

FIG. 7 shows the two active electrodes 12*b* and 13*b*, each shaped in a right angle pie-shaped sector, as in FIG. 5, and the ground electrode 14*b* being of a full circular pattern, the latter of which overlays the composite semicircular portion composed of generally quadrant-shaped sectors 12*b* and 13*b*, when in assembled relationship on opposite sides of the wafer of plate 10.

That is, the present invention provides in the ceramic filter a semicircular portion between and/or bridging the active electrodes and/or by the ground electrode, thereby evolving three combinations which are entirely practical.

The piezoelectric ceramic filters of the present invention, as described above, exhibit a sharp attenuation characteristic in comparison with the piezoelectric ceramic filters of the prior art, particularly in the suppression of spurious responses, for example, below 9 MHz. and above 11.4 MHz. in a specific case, and displays a high selectivity characteristic.

The suppression of spurious responses based on this invention is shown in FIGS. 8 and 8*a*. By experiment at the two frequencies indicated in the graph, the attenuation achieved by using the relative areas of the semicircular portions as defined herein by the various arrangements of the active electrodes and the ground electrode is varied. In FIGS. 8 and 8*a*, the symbol X along the abscissa represents the ratio of the common area between the active electrodes and the ground electrode represented in a linear fashion in terms of the diameter. The ratio is unity or one to one for the piezoelectric ceramic filters of the prior art. It will be observed that in the vicinity where $X=\frac{1}{2}$, or resembling a semicircle, the best response is achieved.

FIG. 9 illustrates the attenuation characteristics exhibited by the present invention represented by a solid line, in comparison with a piezoelectric ceramic filter of the prior art, represented by a dashed line. Marked improvement in the suppression of spurious response is readily apparent.

The piezoelectric ceramic filter of the present invention composed of the illustrated semicircular portions on a rectangular ceramic plate as placed between the active electrodes and a ground electrode provides means of achieving highly desirable attenuation characteristics at low cost. It is apparent that a greatly improved filter has been evolved which achieves the objects and advantages as set forth in the preamble and throughout the specification.

We claim:

1. An improved piezoelectric ceramic filter for use in a frequency range above 1 MHz., and adapted to utilize the thickness expansion or thickness shear mode of the vibration of a thin ceramic plate having opposed surface electrodes, with conductor leads of the electrodes disposed at right angles, said filter comprising in combination:

a. a thin ceramic platelike body having opposite generally flat surfaces;

b. a divided active electrode comprising a pair of active electrode sectors each having arcuate outer peripheries encompassing at least a quadrantlike area together with at least one relatively straight inner marginal side, and said sectors being mounted on one surface of said body with said electrode marginal straight sides spaced slightly apart in parallel;

c. a ground electrode mounted in at least partial peripheral alignment with said active electrode, but on the opposite surface of said body, and corresponding in area size and shape to at least a major portion of that of said active electrode; and

d. said active and ground electrodes facing each other through said ceramic body and having a common overlap area which is of generally semicircular form.

2. An improved filter as defined in claim 1 wherein the divided active electrode sectors are of generally semicircular shape, which together form a generally full circle shape.

3. An improved filter as defined in claim 2 wherein the ground electrode is of semicircular shape having a diametrical side marginal edge disposed at right angles to the corresponding straight marginal sides of said active electrode.

4. An improved filter as defined in claim 1 wherein the divided active electrode sectors are of generally right angular pie shape quadrants with a pair of adjacent edges spaced parallel apart from each other and together forming generally a semicircle.

5. An improved filter as defined in claim 4 wherein said ground electrode is also of semicircular shape and disposed to coincide with that formed by said active electrode.

6. An improved filter as defined in claim 4 wherein said ground electrode is of a generally circular shape.

7. An improved filter as defined in claim 4 wherein said ground electrode is of a uniform full circle form.

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