

[54] **ELECTROMECHANICAL WAVE FILTER**
[72] Inventor: **Emmanuel P. Papadakis**, Acton, Mass.
[73] Assignee: **Bell Telephone Laboratories, Incorporated**,
Murray Hill, N.J.
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[52] U.S. Cl. **333/71, 333/72**
[51] Int. Cl. **H03b 9/20**
[58] Field of Search **333/71, 72;**
310/15-25, 8.5, 8.6, 8.7; 330/116

[56] **References Cited**
UNITED STATES PATENTS

3,064,213 11/1962 Mason **333/71**
2,906,971 9/1959 Mason and Thurston **333/71**

3,015,789 1/1962 Honda et al. **333/72**
3,264,585 8/1966 Poschenrieder **333/72**
3,358,249 12/1967 Kawakami **333/71**
3,290,621 12/1966 Krambeer et al. **333/71**

Primary Examiner—Herman Karl Saalbach
Assistant Examiner—C. Baraff
Attorney—R. J. Guenther and Arthur J. Torsiglieri

[57] **ABSTRACT**
The specification described an electromechanical filter design which is an improvement over the ladder-type torsional filter of U.S. Pat. No. 3,064,213 issued to W. P. Mason on Nov. 13, 1962. Unwanted longitudinal resonances are eliminated by the use of a longitudinal reinforcing member. An improved mounting arrangement is described. It has also been found that the number of transducers necessary for effective operation of this filter can be reduced by one-half.

3 Claims, 6 Drawing Figures

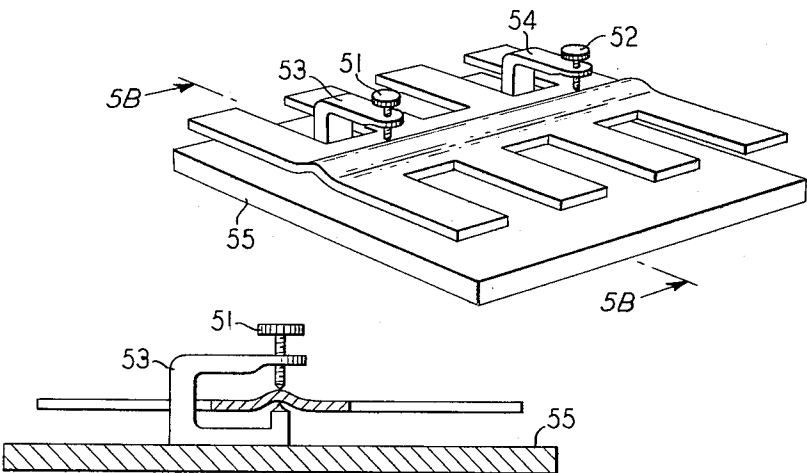


FIG. 1
(PRIOR ART)

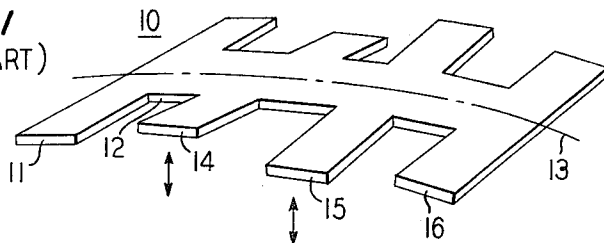


FIG. 2

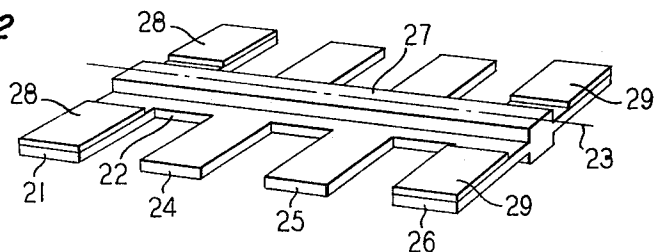


FIG. 3

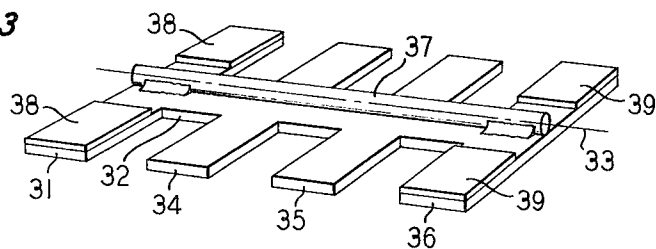


FIG. 4

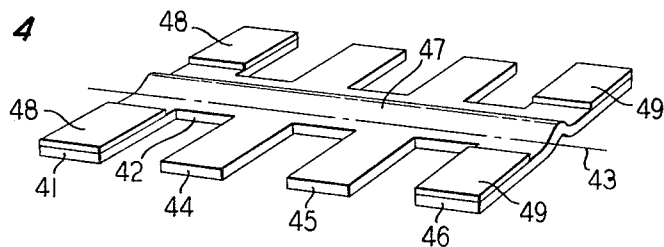


FIG. 5A

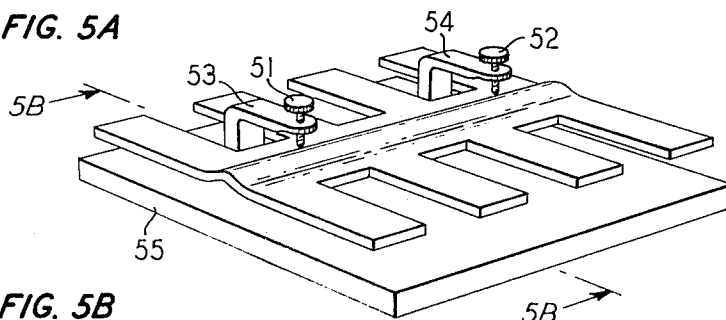
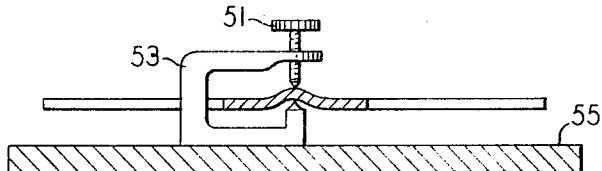


FIG. 5B



INVENTOR
E. P. PAPADAKIS
BY *[Signature]*

ATTORNEY

ELECTROMECHANICAL WAVE FILTER

This invention relates to electromechanical wave transmission systems. More specifically, it concerns improvements in the design of electromechanical filters.

Much recent effort toward improving the design of filter networks has been oriented to high-frequency systems and indeed significant recent advances have been made in the design of filter devices operating in medium and high-frequency ranges.

However there is a renewed interest in low-frequency transmission systems for tone and band selection circuits. Several important applications exist in telephony for tone signaling. The TOUCH-TONE tone signal switching system is now widely used. The use of tone signaling for actuating remote utility meter reading equipment is imminent. The signals used in these applications generally fall in the audio range of a hundred to a several thousand cycles.

A relatively new electromechanical filter design has been found to be especially suitable for these low-frequency applications. This filter design is described in U.S. Pat. No. 3,064,213 issued to W. P. Mason on Nov. 13, 1962. It involves a standard electromechanical transducer, typically a piezoelectric or magnetostrictive transducer, coupled with a mechanical wave filter. The mechanical wave filter comprises a series of elongated bars connected to a central strip at or near their midpoints. The central strip serves as an axis about which the bars vibrate and transmits torsional energy between the bars. The transducers are fixed to the two terminal bars. As compared with its forerunner, this torsional mode filter has the advantage of being essentially two dimensional (although the torsional displacement occurs in the third dimension). This allows the device to be simply cut from a sheet of stock which is very appealing from an economic viewpoint.

It has now been found that this particular form of torsional filter in its prior art form is prone to longitudinal vibrations along the central strip. These longitudinal resonances impair the modal purity of the device and in some cases render it unfit for its intended use.

According to the invention the unwanted longitudinal resonances in the filter design described are eliminated from the frequency band of interest by constructing the central strip joining the bars with a longitudinally extending reinforcement. This can be accomplished for example by forming the central strip with an enlarged cross section or by attaching an auxiliary reinforcing bar to the central strip. In a preferred embodiment a longitudinally extending rib is formed in the central strip at the same time the structure is cut, e.g., by diecutting. Intuitively it can be appreciated that the presence of this central reinforcement does not interfere significantly with the torsional vibration of the transversely extending bars since the reinforcement merely increases the mass of the axis of rotation. However, longitudinal vibration is effectively inhibited.

An important consideration in the design of electromechanical wave filters is the mounting structure. U.S. Pat. No. 3,064,213 describes a wire mount with the wires bonded to each end of the central axis. It can be appreciated that, to the extent that the support structure is rigid, the added torsional impedance of the wires must be taken into account in the mechanical design so that the support structure participates in some predictable way in the resonant structure. The only other alternative is to make the support so resilient that it lends little structural support.

According to a further embodiment of the invention, the filter is supported along the rigid longitudinal axis preferably at torsional node points. This expedient allows for longitudinal rigidity in the support with little effect on the torsional vibration. Furthermore it results in a simpler mechanical structure and one which is more easily assembled.

Also, in contrast with the prior art device which utilizes electromechanical transducers bonded to both sides of the bar structure, the device of this invention in a preferred form requires transducers on one side of the structure only. It has been found that the resonant characteristics of this device are not appreciably different from the prior art devices using twice as many transducers.

These and other aspects of the invention may be more comprehensible in view of the following detailed description. In the drawing:

FIG. 1 is a perspective view of an electromechanical filter constructed according to the principles of the invention;

FIG. 2 is a view similar to that of FIG. 1 illustrating an alternative embodiment;

FIG. 3 is again a similar view showing yet another embodiment;

FIG. 4 is a perspective view showing the filter of FIG. 1 mounted according to an additional aspect of the invention; and

FIGS. 5A and 5B illustrate a support structure for the filters of FIGS. 2-4.

Referring to FIG. 1 there is shown a mechanical wave filter 10 having a structure similar to that described in U.S. Pat. No. 3,064,213 issued Nov. 13, 1962. The filter may be of any conventional rigid material known for use in these devices such as steel, bronze, brass, etc. The figure is intended to illustrate the mechanical displacements and deformations during resonance. A torsional wave is introduced into bar 11 by electromechanical transducers (not shown) on the terminal bars. Torsional energy is transmitted through stem 12 which along with the rest of the central strip, designated here by centerline 13, constitutes the rotational axis of the torsional filter. The displacement of arm 14, caused by the aforementioned torque, in turn transmits energy to the next bar 15 and in a like manner the terminal bar 16 is deflected. Transducers (not shown) on bar 16 sense the movement and provide the output signal. When the structure is designed so that the arms are displaced in a phase relationship the filter is resonant and will efficiently transmit the resonant frequency. The theory of operation of this filter structure is described more completely in the patent referred to above and in U.S. Pat. No. 2,906,971, issued to W. P. Mason and R. N. Thurston on Sept. 29, 1959. To the extent appropriate these disclosures are incorporated herein by reference. The details of the construction of the device for a given resonant frequency depend on many variables including the stiffness of the material and the several dimensions of the basic geometry indicated. However using known design principles those skilled in the art can produce a desired filter device. The filters illustrated in the drawing all happen to be four bar structures. As the number of bars is increased the passband increases according to the well-known ladder theory. Thus the structure in its simplest form is an "H" shape, usually for minimum bandwidth. Most of the practical designs employ from one to eight passive elements (the terminal members being considered active in this context).

As shown in an exaggerated manner in FIG. 1, the center strip along centerline 13 is prone to longitudinal bending. This means that the center portion will support longitudinal resonances that can interfere with the efficient transmission of torsional energy. In fact, devices with this basic construction, and which according to accepted filter design principles should yield good quality filters, have been found to be very inefficient due to the unwanted absorption of energy by the longitudinal resonance.

According to the invention this defect is largely overcome by providing the filter with a reinforced center section.

In a first embodiment shown in FIG. 2 the center strip or resonant axis is made with an enlarged cross section. The reference numerals 21-26 denote elements corresponding to elements 11-16 of FIG. 1. Transducers 28 and 29, disposed as shown with conductive metal coatings on each major face, produce and detect the torsional elastic wave. These transducers are conventional and may have, for example, the structure suggested by the prior art referred to above. The enlarged center strip 27, extending the entire longitudinal dimension along centerline 23, inhibits longitudinal bending. For this purpose it is generally adequate to construct at least a lateral portion of the center strip with a cross section at least 50 percent greater than the normal planar section (e.g., the thickness of the rib members). That is, if the thickness of the planar filter is t then at least a portion of the center strip is

preferably at least 1.5 t . This assures sufficient longitudinal rigidity of the center strip to substantially eliminate any longitudinal modes. Such a structure can be manufactured quite simply from a single sheet of appropriate material by known die-forming techniques.

An alternate approach yielding a functionally equivalent structure is illustrated in FIG. 3. Again the reference numerals 31-36 designate elements corresponding to elements 11-16 of FIG. 1. Transducers are shown at 38 and 39. The stiffening or reinforcing member 37 is, in this case, a separate bar bonded to the central strip as shown. Again it is considered sufficient for the purposes of the invention that the reinforced region have an effective thickness at least 50 percent greater than the normal planar thickness of the central strip.

A preferred form of the invention is shown in FIG. 4. The reference numerals 41 to 46, 48 and 49 correspond directly with similar elements 31 to 36, 38 and 39 of FIG. 3. However, in this embodiment the center strip along centerline 43 is reinforced by deforming the planar filter member to form a reinforcing crease 47. For the requisite rigidity the height of this ridge as measured in the direction normal to the major plane of the filter, should be at least equal to the thickness of the planar portion of the central strip of the filter.

A problem that is common to all filters is the mounting of the filter in a way that does not interfere with the desired resonances. The mounting arrangement recommended in U.S. Pat. No. 3,064,213 for the multiple bar ladder-type electromechanical filter of the general type disclosed herein is a firm steel wire attached to the ends of the filter at the axis of the central strip. As noted in the specification of that patent this mounting, if it is rigid enough to give good support, contributes an added mechanical impedance. Thus the design of the resonator should take into account the mechanical properties of the mount even though these may not be fully ascertainable until the filter is actually mounted (at which point adjustment may be impractical).

According to a further embodiment of this invention the filter is mounted in a novel way that avoids added torsional impedance and is advantageous both mechanically and from the standpoint of economy in manufacture. An exemplary mounting structure is shown in FIG. 5A. The filter 50 is structurally the same as that shown in FIG. 4. It is mounted as shown with mounting screws 51 and 52 retained by supports 53 and 54 and base support 55. The mounting member is shown in more detail in FIG. 5B which is a section at A-A of FIG. 5A. The adjustable screws illustrated, although functional, are intended as symbolic of any number of physically rigid members useful for supporting the filter in the manner shown. For example spring-loaded clips would be economical for supporting the ordinary filter. The vital features are that the contact area between the support and the filter be small, as would be expected, and that the point of contact occur on the reinforcing member, of whichever design chosen, and between the torsionally resonant bars. This assures that the mounting restraint occurs at or near a torsional node point in the resonant structure and thus will not impair the efficiency of the filter. In addition the effective longitudinal stiffness can be further controlled through the use of properly located mounts.

I claim:

1. An electromechanical wave filter comprising as a single

planar body an elongated central member and a plurality of pairs of rib members, the pairs spaced along said central member at substantially equidistant positions and the ribs of each pair extending transversely away from said central member in opposite directions in a single plane, the filter further including at least one pair of electromechanical transducers affixed to each terminal pair of rib members, said transducers adapted to displace or to detect torsional displacement of the rib members with respect to the central member, the invention characterized in that the central member is constructed with a structurally reinforced portion extending substantially along its entire length so as to impart significantly greater longitudinal rigidity than the longitudinal rigidity of the rib members, thereby eliminating undesired longitudinal resonances from the central member, said structurally reinforced portion comprising a region having a thickness of at least 50 percent greater than the thickness of the rib members.

2. An electromechanical wave filter comprising as a single planar body an elongated central member and a plurality of pairs of rib members, the pairs spaced along said central member at substantially equidistant positions and the ribs of each pair extending transversely away from said central member in opposite directions in a single plane, the filter further including at least one pair of electromechanical transducers affixed to each terminal pair of rib members, said transducers adapted to displace or to detect torsional displacement of the rib members with respect to the central member, the invention characterized in that the central member is constructed with a structurally reinforced portion extending substantially along its entire length so as to impart significantly greater longitudinal rigidity than the longitudinal rigidity of the rib members, thereby eliminating undesired longitudinal resonances from the central member, said structurally reinforced portion comprising a longitudinal crease in the central member, the crease having an average height at least equal to the thickness of the central member.

3. An electromechanical wave filter comprising as a single planar body an elongated central member and a plurality of pairs of rib members, the pairs spaced along said central member at substantially equidistant positions and the ribs of each pair extending transversely away from said central member in opposite directions in a single plane, the filter further including at least one pair of electromechanical transducers affixed to each terminal pair of rib members, said transducers adapted to displace or to detect torsional displacement of the rib members with respect to the central member, the invention characterized in that the central member is constructed with a structurally reinforced portion extending substantially along its entire length so as to impart significantly greater longitudinal rigidity than the longitudinal rigidity of the rib members, thereby eliminating undesired longitudinal resonances from the central member and further including at least two support means for the filter, each support means comprising a pair of mounting members contacting the central strip of the filter at opposite sides thereof and at a position intermediate the longitudinal centerline of two pairs of rib members, said position being substantially at a torsional mode node point.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,638,145 Dated January 25, 1972

Inventor(s) Emmanuel P. Papadakis

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, line 13, TOUCH-TONE

should read

TOUCH-TONE®

Signed and sealed this 15th day of August 1972.

(SEAL)
Attest;

EDWARD M. FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents