

Jan. 27, 1942.

W. P. MASON

2,271,200

WAVE FILTER.

Filed July 19, 1939

FIG. 1

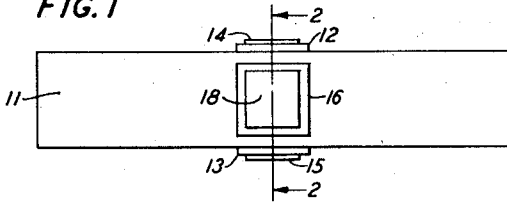


FIG. 2

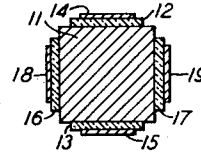


FIG. 3

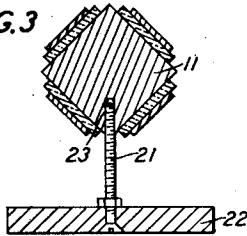


FIG. 4

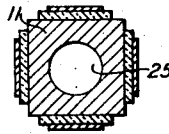


FIG. 5

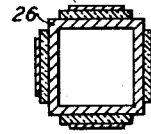


FIG. 6

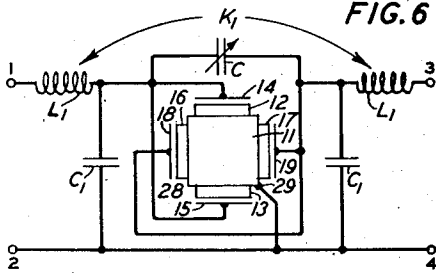


FIG. 7

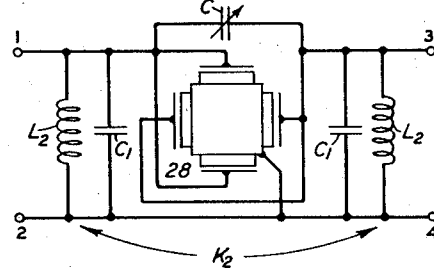


FIG. 8

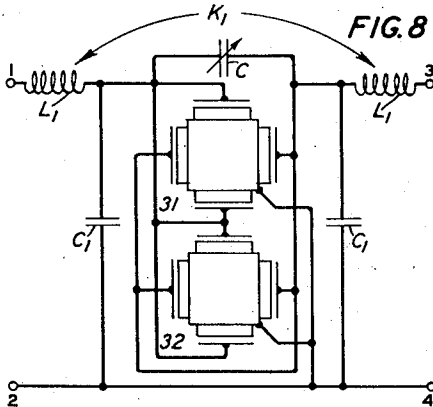
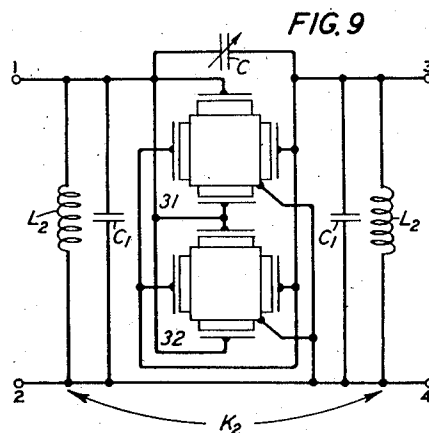


FIG. 9



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2,271,200

WAVE FILTER

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Application July 19, 1939, Serial No. 285,237

20 Claims. (Cl. 178-44)

This invention relates to wave filters and more particularly to those which employ as reactance elements metallic vibrators electromechanically coupled to the circuit by means of piezoelectric plates.

An object of the invention is to improve the transmission characteristics of wave filters which employ metallic vibrators as reactance elements.

A feature of the invention is a metallic vibrator with electromechanical coupling means including a pair of piezoelectric plates associated with two sides of the vibrator and a second pair of plates associated with the other two sides.

In accordance with the invention there are provided wave filters of inherently either high or low image impedance which employ one or more electromechanical vibratory elements of special construction. The element consists of a metallic vibrator preferably of rectangular cross-section, a pair of piezoelectric plates associated with two sides of the vibrator for producing longitudinal vibrations therein and a second pair of piezoelectric plates associated with the other two sides of the vibrator for picking up the mechanical vibrations and reconverting them into electrical vibrations. Each plate, of course, has associated therewith a suitable electrode for making electrical connection therewith. When the plates are thus associated with different sides of the vibrator they may be located centrally with respect to the length of the vibrator and in this way the introduction of extraneous modes of vibration is minimized. The vibrator is preferably made of a metal or an alloy having a low temperature coefficient of frequency. The plates may be made from any piezoelectric material but plates of Rochelle salt are preferred because of their high piezoelectric activity.

The vibrator is preferably supported at a node of motion. When the fundamental frequency is utilized such a node will be found at the center of the vibrator and therefore the vibrator is preferably supported at this point. When the piezoelectric plates are also located at the center of the vibrator the support may conveniently contact the vibrator at a corner so as not to interfere with the plates.

In order to increase the band width obtainable with the filter it is desirable to increase the electromechanical coupling between the plates and the vibrator. This coupling may be increased by removing material from the vibrator along its longitudinal axis. The piezoelectric driving force will remain the same but the effective elastic constant of the vibrator will be decreased, and therefore the piezoelectric-mechanical coupling will be increased. The resonant frequency of the vibrator and the static impedance of the crystal plates are not changed by this modification. In the limiting case the vibrator may take the form

of a tube having a square or rectangular cross-section.

The filter circuits disclosed are of the bridged-T type in which the series arms of the T are constituted by an electromechanical vibrator of the type described above. Two oppositely disposed plates of the vibrator are connected together and to an input terminal of the filter, the other two plates are connected together and to the corresponding output terminal and the metallic vibrator is connected to the remaining filter terminals. A bridging impedance branch, usually including a capacitor, is connected between the two sets of plates. Two shunt end capacitors are connected, respectively, between each set of plates and the metallic vibrator. The circuit is completed by the addition of two end inductors, connected in series for the low impedance filter and in shunt for the high impedance filter. In a modified form of the invention two electromechanical vibrators, connected in parallel, are used in a filter circuit.

The filters are of the wide-band variety; that is, they have transmission bands which extend between selected cut-off frequencies. When a single electromechanical vibrator is used the filter will have a peak of attenuation at infinite frequency in the case of the series-connected end inductors, and at zero frequency in the case of the shunt-connected end inductors. In addition, in either case, there will be a second peak which may be placed either above or below the transmission band, depending upon the poling of the piezoelectric plates. If mutual inductance is provided between the end inductors the peaks at zero or infinity may be moved in toward the transmission band, or even located on the other side of the band. In the filter employing two vibratory elements a peak of attenuation may be provided on each side of the transmission band, and if mutual inductance is used three arbitrarily placed peaks are obtainable.

The nature of the invention will be more fully understood from the following detailed description and by reference to the accompanying drawing, of which:

Fig. 1 shows one form of the electromechanical vibratory element of the invention;

Fig. 2 is a cross-sectional view taken at the center of the element of Fig. 1;

Fig. 3 shows the element of Fig. 1 supported at a corner;

Figs. 4 and 5 are cross-sectional views of modified elements in which material has been removed along the longitudinal axis of the vibrator;

Figs. 6 and 7 show, respectively, low impedance and high impedance filter circuits in accordance with the invention each employing a single electromechanical vibratory element; and

Figs. 8 and 9 show, respectively, low and high

impedance filter circuits each employing two electromechanical vibratory elements.

Referring to the drawing in more detail, Fig. 1 is a side view and Fig. 2 is a cross-sectional view taken along the line 2—2 of one form of the electromechanical vibratory element. The device comprises a metallic vibrator 11 in the form of a bar of square cross-section, a pair of piezoelectric plates 12, 13 with associated electrodes 14, 15 secured to two opposite faces of the vibrator and a second pair of piezoelectric plates 16, 17 with associated electrodes 18, 19 secured to the other two faces. The vibrator 11 is preferably made of an alloy having a low temperature coefficient of frequency such, for example, as one consisting of approximately 63 per cent iron and 37 per cent nickel. When longitudinal vibrations are to be utilized, that is, when the vibrator 11 elongates and contracts in the direction of its length, the piezoelectric plates are preferably placed midway between the ends of the vibrator in order to avoid the introduction of extraneous modes of vibration. In accordance with the invention both the driving plates and the pick-up plates may thus be centrally located by placing one pair on opposite sides and the other pair on the remaining sides of the vibrator. The plates are made of any suitable piezoelectric material but Rochelle salt is preferred due to its high piezoelectric activity.

For best results the vibrator is supported at a node of motion and when the fundamental mode is used a node is to be found at the center. Therefore, as shown in the cross-sectional view of Fig. 3, the vibrator 11 is preferably centrally supported at a corner, for example, by means of a screw 21 which projects from a base 22 and screws into a tapped hole in the vibrator as shown at 23. By supporting the vibrator at a corner the central support does not interfere with the plates, which are also centrally located. Harmonics of the fundamental frequency, may, of course, be utilized, if desired.

The cross-sectional view of Fig. 4 shows a modified form of the vibrator 11 which is the same as the one shown in Figs. 1 and 2 except that material has been removed along the longitudinal axis, as indicated by the hole 25. Building the vibrator in this form increases the electromechanical coupling between the piezoelectric plates and the vibrator and permits the provision of a wider transmission band in the filter of which the element forms a part. In the limiting case the vibrator may take the form of a tube 26 of rectangular or square cross-section as shown in Fig. 5.

Fig. 6 is a schematic circuit of a wave filter in accordance with the invention having a pair of input terminals 1, 2 and a pair of output terminals 3, 4 and employing as a component part an electromechanical vibratory element 28 of the type described above. The filter is of the symmetrical, unbalanced, bridged-T type in which the series arms of the T are furnished by the element 28. Two oppositely disposed electrodes 14, 15 are connected together and to an input terminal 1, and the other pair of electrodes 18, 19 are connected to the corresponding output terminal 3. A point 29 of the vibrator is connected to the remaining filter terminals 2 and 4. A bridging impedance branch including a capacitor C is connected between the two sets of electrodes. Two shunt end capacitors C_1 , C_2 are connected, respectively, between each set of elec-

trodes and the grounding point 29 of the vibrator. The two series inductors L_1 , L_2 connected at the respective ends of the filter complete the circuit. The path between terminals 2 and 4 may be grounded or otherwise fixed in potential.

By properly proportioning the component elements the filter of Fig. 6 may be designed to transmit freely a band extending between two preassigned cut-off frequencies. There will be a peak of attenuation at infinity and a second peak either above or below the transmission band. If all of the crystal plates are so poled that when the vibrator 11 expands a positive charge is generated on the surface of each plate the second peak will appear at some frequency below the lower cut-off. On the other hand, if an expansion of the vibrator creates a positive charge on one pair of oppositely disposed plates and a negative charge on the other pair of plates this peak will occur at a frequency above the upper cut-off. The location of this peak depends principally upon the value of the bridging capacitor C, and therefore this capacitor may be made variable, as indicated by the arrow, to facilitate the adjustment of the peak. If mutual inductance is provided between the end inductors, as indicated by the coefficient of coupling K_1 , the peak at infinity may be moved in toward, or to the lower side of, the band, depending upon the sign of the mutual inductance. It is apparent, therefore, that by a proper setting of the capacitor C and a proper choice of mutual inductance both peaks may be located as desired.

The filter of Fig. 6, with series end inductors, has an inherently low image impedance. If a high image impedance is desired the circuit of Fig. 7, in which the end inductors L_1 , L_2 are connected in shunt, is to be preferred. The other component elements in Fig. 7 are the same as those in Fig. 6 but their values may, of course, be different. The filter of Fig. 7 will ordinarily have a peak of attenuation at zero frequency and a second peak either above or below the band, depending upon the poling of the piezoelectric plates of the element 28, as explained above in connection with the filter of Fig. 6. By the introduction of mutual inductance between the two end inductors, as indicated by the coefficient of coupling K_2 , the peak at zero may be moved up to any desired frequency, either below or above the transmission band.

The filter circuit of Fig. 8 is similar to that of Fig. 6 except that in the former two electromechanical vibratory elements 31, 32, connected in parallel, are employed instead of one. Besides a peak of attenuation at infinity the filter will have a peak on each side of the transmission band if in one element all of the piezoelectric plates are of the same polarity while in the other element one pair of plates differs in polarity from the other pair. The peak at infinity may be moved down to any desired frequency if mutual inductance is provided between the two end inductors. The filter will have an inherently low image impedance.

The high impedance filter employing two electromechanical vibratory elements is shown schematically in Fig. 9. The circuit of Fig. 9 differs from that of Fig. 8 only in that in the former the end inductors are connected in shunt instead of in series. The filter may be designed to have an attenuation peak on each side of the transmission band and a third peak at zero frequency. This latter peak may be moved up to any desired frequency by the introduction of mu-

tual inductance between the two end inductors.

What is claimed is:

1. A wave filter including as an impedance element an electromechanical vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates secured respectively to said sides and means for making electrical connections to said plates, said plates being centrally disposed with respect to the length of said vibrator.

2. A wave filter having a pair of input terminals and a pair of output terminals and including an electromechanical vibratory system, a pair of shunt connected capacitors, a pair of inductors connected at the ends of the filter and a bridging impedance branch including a third capacitor connected in an electrical path between one input terminal and the corresponding output terminal, said vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates secured respectively to said sides, electrical connections from said one input terminal to two of said plates, electrical connections from said corresponding output terminal to the remaining plates and an electrical connection from said vibrator to the remaining filter terminals, and said component elements being so proportioned with respect to each other and with respect to two preassigned cut-off frequencies that the filter has a band of free transmission extending between said frequencies and substantial attenuation outside of said band.

3. A wave filter in accordance with claim 2 in which said inductors are connected in series at the respective ends of the filter.

4. A wave filter in accordance with claim 2 in which said inductors are connected in shunt at the respective ends of the filter.

5. A wave filter in accordance with claim 2 in which said inductors are inductively coupled.

6. A wave filter in accordance with claim 2 which includes a second similar electromechanical vibratory system connected in parallel with said first electromechanical vibratory system.

7. A vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates of Rochelle salt secured respectively to said sides, means for making electrical connections to said plates and means for supporting said vibrator on a corner.

8. A vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates secured respectively to said sides and means for making electrical connections to said plates, said plates being centrally disposed with respect to the length of said vibrator.

9. A vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates of Rochelle salt secured respectively to said sides and means for making electrical connections to said plate.

10. A vibratory system comprising a mechanical vibrator having four sides, four piezoelectric plates secured respectively to said sides, means for making electrical connections to said plates and means for supporting said vibrator on a corner at a node of motion.

11. A vibratory system comprising a metallic bar, a pair of oppositely disposed piezoelectric plates of Rochelle salt secured to two sides of said bar for producing longitudinal mechanical vibrations therein, a second pair of oppositely disposed piezoelectric plates of Rochelle salt se-

cured to two other sides of said bar for picking up said mechanical vibrations and converting them into electrical vibrations and means for supporting said bar at a corner.

12. A vibratory system comprising a metallic bar, a pair of oppositely disposed piezoelectric plates secured to two sides of said bar for producing longitudinal mechanical vibrations therein and a second pair of oppositely disposed piezoelectric plates secured to two other sides of said bar for picking up said mechanical vibrations and converting them into electrical vibrations, material having been removed along the longitudinal axis of said bar to decrease the mass of the bar and thereby increase the electromechanical coupling between the bar and the associated piezoelectric plates.

13. A vibratory system comprising a metallic bar, a pair of oppositely disposed piezoelectric plates secured to two sides of said bar for producing longitudinal mechanical vibrations therein, a second pair of oppositely disposed piezoelectric plates secured to two other sides of said bar for picking up said mechanical vibrations and converting them into electrical vibrations and means for supporting said bar at a corner.

14. A vibratory system comprising a metallic bar, a pair of oppositely disposed piezoelectric plates secured to two sides of said bar for producing longitudinal mechanical vibrations therein, a second pair of oppositely disposed piezoelectric plates secured to two other sides of said bar for picking-up said mechanical vibrations and converting them into electrical vibrations and means for supporting said bar at the center on a corner, said plates being centrally disposed with respect to the length of said bar.

15. A vibratory system comprising a metallic tube of rectangular cross-section and four piezoelectric plates of Rochelle salt, one of said plates being secured to each of the sides of said tube and said plates being centrally disposed with respect to the length of said tube.

16. A vibratory system comprising a metallic tube of rectangular cross-section and four piezoelectric plates, one of said plates being secured to each of the sides of said tube and said plates being centrally disposed with respect to the length of said tube.

17. A wave filter in accordance with claim 2 in which said two piezoelectric plates connected to said one input terminal are on opposite sides of said mechanical vibrator.

18. A wave filter in accordance with claim 2 in which said piezoelectric plates are of Rochelle salt.

19. A wave filter in accordance with claim 2 which includes a second similar electromechanical vibratory system connected in parallel with said first electromechanical vibratory system, one of said systems having piezoelectric plates all of the same polarity and the other of said systems having one pair of plates which differ in polarity from the other associated pair of plates.

20. A wave filter in accordance with claim 2 in which said mechanical vibrator is a metallic bar with material removed along its longitudinal axis to decrease the mass of the bar and thereby increase the electromechanical coupling between said vibrator and its associated piezoelectric plates.

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DISCLAIMER

2,271,200.—*Warren P. Mason*, West Orange, N. J. **WAVE FILTER**. Patent dated January 27, 1942. Disclaimer filed April 22, 1942, by the assignee, *Bell Telephone Laboratories, Incorporated*.

Hereby enters this disclaimer to claims 1, 8, and 9 of said Letters Patent.

[*Official Gazette May 19, 1942.*]

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