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COMBINED MAGNETOSTRICTION AND PIEZOELECTRIC SELECTIVE DEVICE

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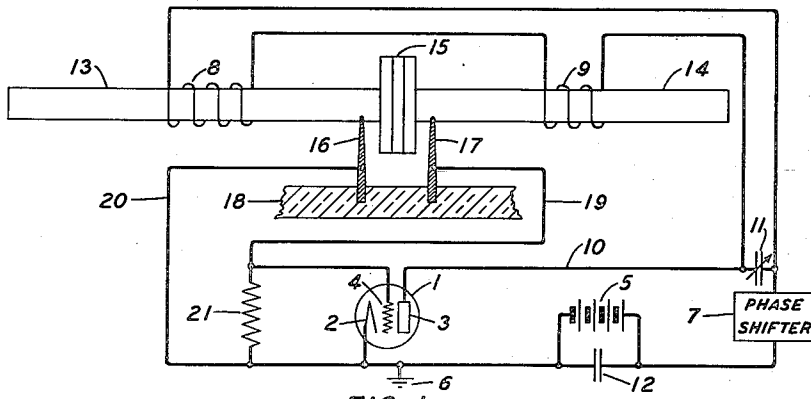


FIG. 1

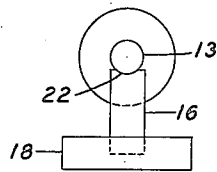


FIG. 2

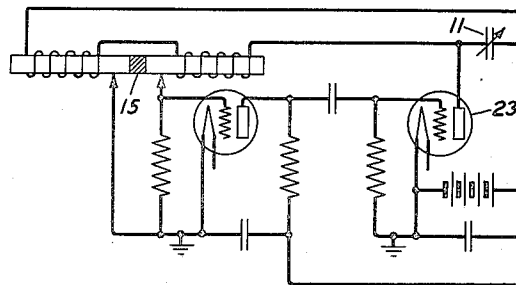


FIG. 3

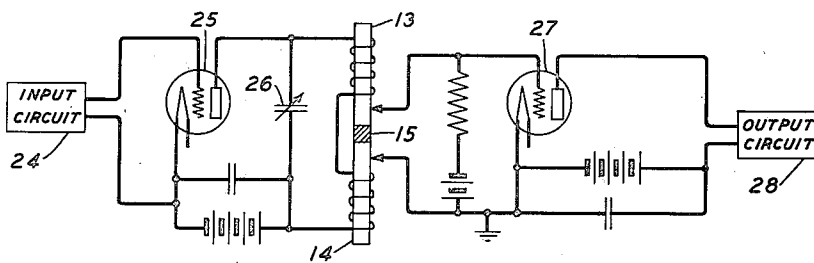


FIG. 4

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COMBINED MAGNETOSTRICTION AND PIEZOELECTRIC SELECTIVE DEVICE

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12 Claims. (Cl. 178-44)

This invention relates to combined magnetostriction and piezoelectric selective devices and more particularly to selective transmission circuits and frequency control circuits embodying such devices.

An object of the invention is to provide electric wave frequency selective apparatus in which advantage may be taken of the low damping of vibrating rods or bars.

10 A principal feature of the invention resides in the conversion of electric wave energy to mechanical vibrations by a magnetostriction device and to re-conversion of the resultant mechanical vibrations to electrical oscillations by piezoelectric apparatus.

15 Another feature of the invention is a magnetostrictively driven mechanical resonator to which magnetostrictive forces are supplied symmetrically with respect to the mounting in order to simplify the motion involved and to enable a simple mounting to be used.

20 Another aspect of the invention relates to control of the frequency of an electron discharge oscillator by the mechanical resonance of a combined magnetostriction and piezoelectric device.

25 In accordance with the invention, a tuned magnetostrictive rod or bar mounted to vibrate freely in a longitudinal mode and having an associated driving magnetic field winding is rigidly connected to a piezoelectric element in such manner that an alternating electromotive force of the natural frequency of the tuned bar applied to the field winding causes the bar to be set in vibration so as to drive the piezoelectric element.

30 The novel features which are characteristic of the invention are pointed out with particularity in the appended claims. The invention itself, however, both as to the details of its organization and its mode of operation will be best understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates schematically the circuits of a vacuum tube oscillator involving a combined magnetostriction and piezoelectric selective device for determining the frequency of the oscillations produced, Fig. 2 is an end view of the selective device of Fig. 1, Fig. 3 shows a modification of the circuit of Fig. 1 using a tandem amplifier and Fig. 4 illustrates the use of the selective device in an ordinary transmission circuit.

50 Referring to Fig. 1 the oscillator comprises an electron discharge device 1 of any well-known type having a cathode 2, anode 3 and impedance control element 4. Space current is supplied by a source 5 of unidirectional current connected in

a path extending from cathode 2 to anode 3 via ground 6, source 5, phase shifter 7, windings 8 and 9 and conductor 10. A variable capacity tuning condenser 11 is connected in shunt to the windings 8 and 9 to form with them an oscillatory circuit of the frequency of the oscillations to be produced. A large capacity element 12 is connected in shunt to source 5.

The magnetostriction windings 8 and 9 are symmetrically positioned with respect to a two-part rod or bar 13, 14 of magnetostrictive material between the adjacent ends of which is cemented a piezoelectric element 15. The bar rests loosely on conducting supporting members 16 and 17 which are mounted on a base 18 of insulating material. Conductors 19 and 20 connect the supporting members with opposite terminals of a high resistance element 21 which is also connected between the input electrodes 2 and 4 of electron discharge device 1. It will accordingly be apparent that electrical oscillations occurring in the oscillatory circuit 8, 9, 11 cause magnetostrictive bar 8, 9 to be set in longitudinal vibration and to impress stresses upon piezoelectric element 15. The element 15 accordingly generates a piezoelectric electromotive force between the conducting bar portions 13 and 14 cemented to its opposite faces and this electromotive force is impressed by conductors 19 and 20 upon the input circuit of the device 1. If the phase of the input electromotive force be properly related to that of the alternating component of the anode current of device 1, oscillations will be sustained. To insure this relationship is the purpose of phase shifter 7.

35 The rods 13 and 14 may consist of any magnetostrictive material such as Monel metal, nichrome, invar or nickel. Nickel is particularly suitable because of its relatively high magnetostrictive activity. In order to reduce damping the supports 16 and 17 are placed at points closely adjacent the center of the bar at which the longitudinal motion of the bar is small. The parts 13, 14 of the bar cemented to the piezoelectric element preferably with flake shellac have end portions adjacent the crystal coextensive in area therewith to provide sufficient bond to withstand the high mechanical stresses involved. The remainder of the bar is of much smaller cross sectional area primarily for the reason that it is desired to reduce to a minimum air damping occurring at the free ends of the bar in consequence of the rapid longitudinal vibrations of these ends. The supporting members 16 and 17 are slightly grooved as indicated at 22, Fig. 2, to

prevent lateral displacement of the vibrating bar. In one example in which oscillations at about 8521 cycles per second were produced the bar consisted of tool steel rods one-half inch in diameter and having end portions adjacent the piezoelectric element one and one-half inches in diameter. The natural oscillation frequency of such a bar is substantially that given by the formula for a midsupported bar:

$$f = \frac{1}{2L} \sqrt{\frac{E}{d}}$$

where f is frequency in cycles per second, L is length of the rod in centimeters, E is Young's modulus in dynes/square centimeters and d is the density in grams per cubic centimeters.

The piezoelectric element, if quartz is used, should preferably be of the well-known Curie or perpendicular face cut. It should have such thickness that its natural period of vibration in the thickness direction is far removed from that of the rod.

Fig. 3 illustrates an alternative form of vacuum tube oscillator differing principally in that a second electron discharge device 23 which serves to increase the amplification and also to reverse the phase of the output oscillations is employed. The phase shifter is accordingly dispensed with. The phase shifter may also be omitted from the circuit of Fig. 1 and an approximate phase shift of 180° obtained by merely reversing the connections of conductors 19 and 20 with respect to input circuit resistance 21.

Oscillating circuits of the types disclosed in Figs. 1 and 3 may be employed either as sources of standard frequency electrical oscillations or for supersonic frequency sound transmission since the bars 13, 14 set up vibrations in the adjacent atmosphere.

Fig. 4 illustrates the use of the selective device as a filter in a transmission circuit. Input circuit 24 which may comprise a remote transmitting station or a local source of oscillations is connected to the input circuit of an asymmetrically transmitting electron discharge repeater 25 to the output circuit of which a magnetostriction-piezoelectric selector is connected. Tuning condenser 26 like the similar tuning condensers 11 of Figs. 1 and 3 assists in matching the internal alternating current impedance of the space discharge path of device 25 and the impedance of the external output circuit to which the device 25 is connected. The vibrations induced in bar 13, 14 and piezoelectric element 15 set up piezoelectromotive forces in the input circuit of another thermionic repeater 27, the output circuit 28 of which may comprise a local or a remote indicator or communication receiver. The selective characteristics of the device 13, 14, 15 are such that only oscillations falling within a narrow band centering at approximately the resonance frequency of bar 13, 14 are transmitted from circuit 24 to circuit 28.

Although the invention has been disclosed in several embodiments it is to be understood that these are illustrative only and that it is not to be restricted thereto but only by the scope of the appended claims.

What is claimed is:

1. A selective device comprising an input circuit, an output circuit, a magnetostrictive element tuned to the frequency of oscillations which it is desired to transmit from said input circuit to said output circuit connected to said input circuit, a piezoelectric element having all its natural peri-

ods of vibration remote from that of the magnetostrictive element, a mounting for said piezoelectric element, means symmetrically connecting said magnetostrictive element to said piezoelectric element to permit transfer of mechanical energy from the magnetostrictive element to the piezoelectric element without imposing substantial stress on said piezoelectric element relative to its supports, and means connected to the piezoelectric element and to the output circuit to impress corresponding electrical oscillations of the desired frequency derived from the piezoelectric element upon the output circuit.

2. A selective system comprising an input circuit having input terminals, an output circuit having output terminals and means highly selective for oscillations of a desired frequency and discriminating strongly against oscillations of undesired frequencies, connecting said input circuit to said output circuit to transfer energy of the desired frequency while suppressing energy of undesired frequencies, said means comprising a magnetostriction element tuned to oscillations of the desired frequency, a piezoelectric element, means for supporting said piezoelectric element physically symmetrically connected to the magnetostrictive element in energy transfer relation to enable said magnetostrictive element to drive said piezoelectric element without producing substantial stress between the piezoelectric element and its supporting means, said piezoelectric element having such widely different natural frequency from that of the magnetostrictive element as to transmit energy of the desired oscillation frequency and relatively wide ranges of adjacent frequency oscillations with little discrimination whereby the selective system as a whole operates to transfer oscillations of the desired frequency from the input circuit to the output circuit with a selectivity determined substantially wholly by the selective characteristics of the magnetostriction element.

3. A frequency selective energy transmission system for transmitting oscillations of a desired frequency comprising an input circuit, a load circuit to which oscillations of said desired frequency are to be applied, and an electromechanical filter connected to both the input circuit and the load circuit for selectively transmitting therebetween oscillations of the desired frequency and for strongly discriminating against oscillations of frequency differing considerably therefrom, said filter comprising a magnetostriction element tuned to the frequency of the desired oscillations for converting electrical oscillations to mechanical oscillations of the same frequency, means connected to said input circuit for producing a magnetic field in magnetizable relation to the magnetostrictive element to tend to set up oscillations therein corresponding to currents traversing the input circuit, and a piezoelectric element having no natural frequency in the neighborhood of the desired oscillation frequency and physically connected to the magnetostriction element for converting mechanical oscillations of the desired frequency supplied thereto by the magnetostriction element to corresponding electrical oscillations of the desired frequency.

4. A resonator comprising a piezoelectric element, an elongated massive member cemented at one end to a face of said element, a similar massive member cemented at one end to the opposite face of said element, and means for supporting said structure to permit substantially free longitudinal vibration thereof.

5. A resonator comprising a piezoelectric element, an elongated massive member cemented at one end to a face of said element, a similar massive member cemented at one end to the opposite face of said element, the cross-sectional area of said element and of the ends of the members cemented thereto greatly exceeding the cross-section of the principal portions of said members, and means for supporting said structure to permit substantially free longitudinal vibration thereof.

6. A piezoelectric element comprising a plate of quartz, the principal faces of which are parallel to the optical axis and perpendicular to an electrical axis of the mother crystal, a rod of magnetostrictive material having one end greatly enlarged with respect to the cross-section of the remainder of said rod, said enlarged member being cemented to one of the principal faces of said piezoelectric plate, a similar rod of magnetostrictive material similarly attached to the opposite principal face, means for supporting said rods in the region of the piezoelectric element to permit longitudinal vibration of the assemblage of the piezoelectric element and rods, and means for subjecting the rods to magnetostrictive action to simultaneously produce pressure changes on the opposite principal faces to which they are respectively cemented whereby said piezoelectric plate is caused to develop differences of potential between its principal faces.

7. Means for converting energy comprising a coil to which currents may be supplied, a two-part rod of magnetostrictive material within said coil, a piezoelectric element, the two parts of the rod being separated from each other by and cemented to the piezoelectric element at opposite surfaces thereof, means for supporting the assemblage of the piezoelectric element and two-part rod for longitudinal vibration, and a conductor connected to each part of the rod forming one terminal of a circuit for transmitting piezoelectric electromotive forces from the piezoelectric element.

8. A frequency selective apparatus comprising a pair of longitudinally aligned rods of magnetostrictive material, a piezoelectric plate cemented to the adjacent ends of the rods and serving to insulate them electrically from each other, an input circuit including a magnetic winding so disposed as, when energized by current therein, to set up a longitudinal field in the rods whereby the rods may be caused to undergo magnetostrictive vibrations, means supporting the assemblage of longitudinally aligned rods and piezoelectric plate in horizontal position to permit free longitudinal vibrations thereof, and an output circuit comprising two output terminal leads electrically connected respectively to the rods whereby piezoelectric electromotive forces developed therein by the piezoelectric plate may be derived from said frequency selective apparatus.

9. A frequency selective coupling for transmitting waves approximating in frequency a certain desired frequency comprising an input circuit to which currents of various frequencies may be supplied, means connected to said input circuit to establish an electromagnetic field varying in accordance with the currents in the input circuit, a magnetostrictive member in magnetizable rela-

tion to the electromagnetic field to respond thereto by setting up magnetostrictive vibrations, said member being mechanically resonant at substantially the frequency which it is desired to transmit, a piezoelectric element connected to the magnetostrictive member to receive mechanical vibrations therefrom and having its natural period of vibration in the direction of the impressed vibrations far removed from the mechanical resonance frequency of the magnetostrictive member, and means connected to the piezoelectric element to receive therefrom electromotive forces developed in the piezoelectric element in response to the mechanical vibrations transmitted to the piezoelectric element by the magnetostrictive member.

10. A selective device comprising an elongated member supported at its central portion at a nodal point for longitudinal vibration, an energy input means connected to the member for impressing forces thereon which are symmetrical with respect to its support and which are so directed as to set said member into longitudinal vibration, and energy output means connected to said member to derive therefrom energy corresponding in frequency to that of its longitudinal vibration and substantially free of components of energy of the other frequencies which may be impressed upon the input means.

11. A filter comprising an input winding, an elongated magnetic member, means for horizontally supporting the elongated member in the region of its central nodal point for longitudinal vibration including supports upon which it loosely rests, the input winding being so positioned with respect to the elongated member as to impress thereon magnetomotive forces tending to induce longitudinal vibrations and which are symmetrical with respect to the supports, and energy output means connected to said member to derive therefrom energy corresponding in frequency to that of its longitudinal vibration and substantially free of components of energy of the other frequencies which may be impressed upon the input winding.

12. A combined magnetostrictive and piezoelectric filter comprising an input coil, a two-part elongated magnetic member having its parts cemented at their adjacent ends to the respectively opposite faces of a piezoelectric element, means for horizontally supporting the elongated member in the region of its central nodal point for longitudinal vibration including supports upon which it loosely rests, the input coil being so positioned with respect to the elongated member as to impress thereon magneto-motive forces tending to induce longitudinal vibrations and which are symmetrical with respect to the supports, and two output terminals electrically connected respectively to the two parts of the magnetic member to derive therefrom the electromotive force generated between the opposite faces of the piezoelectric element in consequence of the varying pressures exerted thereon by the vibrating elongated member, the electrical connections being of such character as to impose no additional mechanical load upon the elongated vibrating member.

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