United States Patent [19]

Defebvre et al.

[11] **3,787,786**

[45] **Jan. 22, 1974**

[54] **CONTINUOUSLY VARIABLE ULTRASONIC DELAY LINE**

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[22] Filed: **Nov. 9, 1972**

[21] Appl. No.: **304,950**

[30] **Foreign Application Priority Data**

Nov. 10, 1971 France 71.40292
Oct. 31, 1972 France 72.38716

[52] **U.S. Cl.** ..... **333/30 R,** 333/72, 310/8.1, 310/9.8

[51] **Int. Cl.** **H03h 9/20,** H03h 9/30, H01v 7/00

[58] **Field of Search** ..... 333/30 R, 72; 310/8.1, 9.7, 310/9.8

[56] **References Cited**

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Attorney, Agent, or Firm—John W. Malley et al.

[57] **ABSTRACT**

Delay line comprising an extended piezoelectric element and two input and output electrode systems cooperating with the surface of this element, characterized in that at least one of the two systems comprises at least one movable part which follows the longitudinal direction of the piezoelectric element, this movable part forming an upper electrode situated close to the active face of the piezoelectric element.

Application to the realization of ultrasonic delay lines with continuous variation.

7 Claims, 7 Drawing Figures

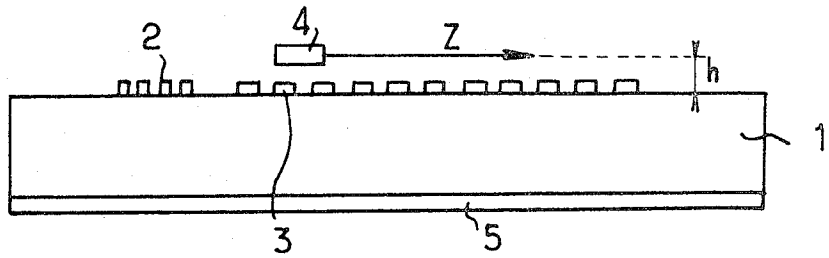


FIG. 1

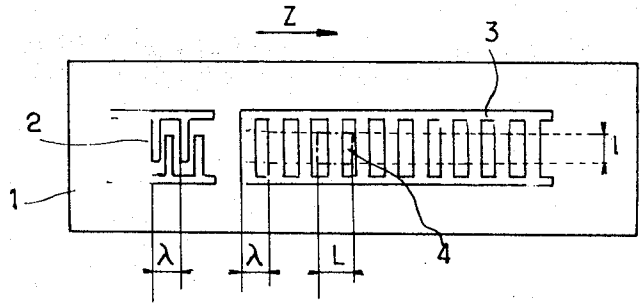


FIG. 2

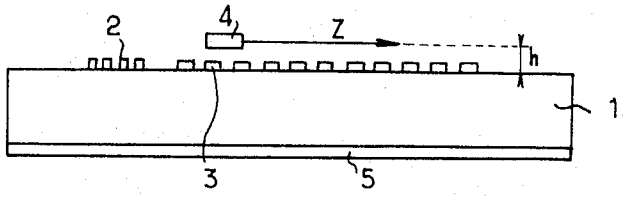
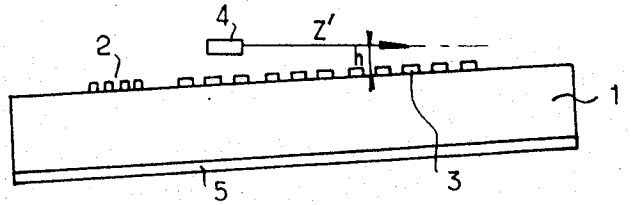


FIG. 3



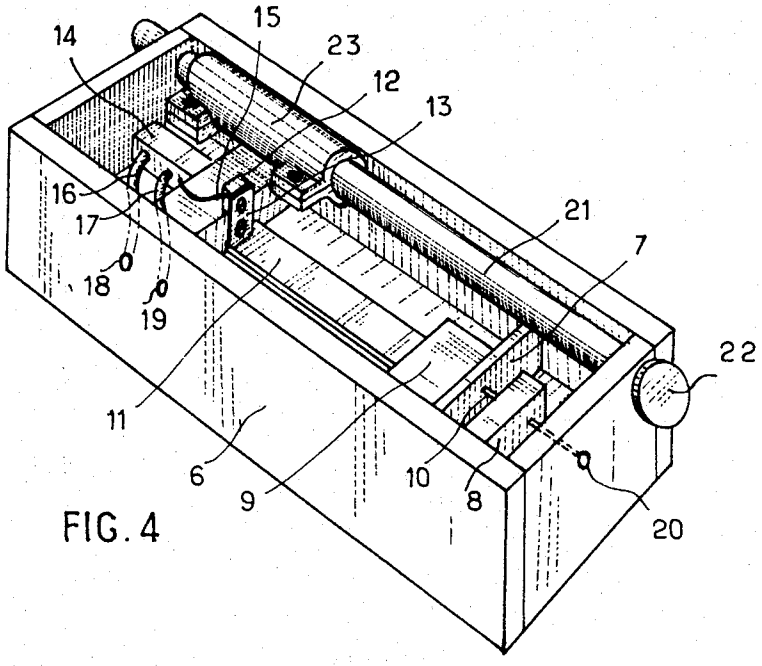


FIG. 4

FIG. 5

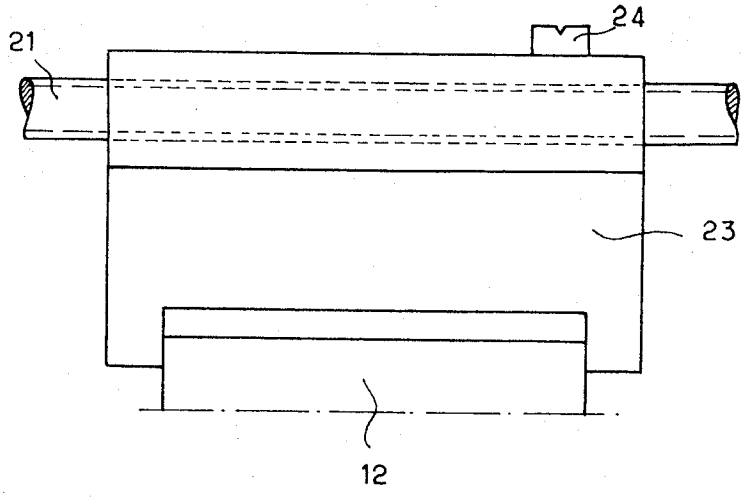


FIG. 6

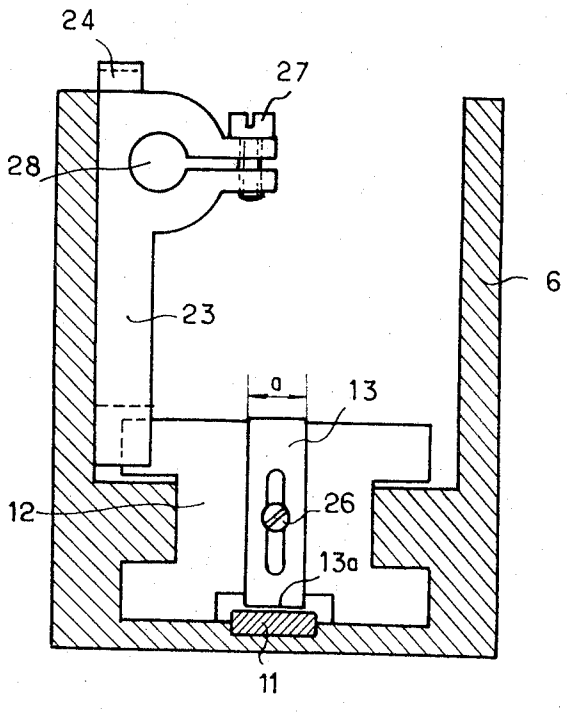
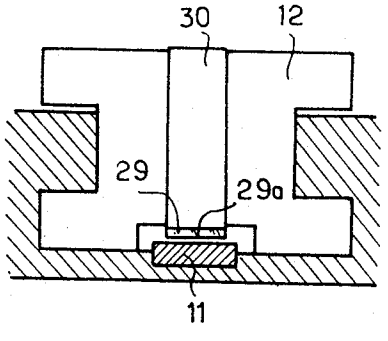


FIG. 7



CONTINUOUSLY VARIABLE ULTRASONIC DELAY LINE

The present invention relates to acoustical delay lines of the type comprising an extended piezoelectric element plus two systems of input (or emitter) and output (or receiver) electrodes, co-operating with the surface of said element.

Propagation of mechanical sound waves on the surface of said element delays electric input signals, in a way obviously depending on the time of propagation.

The known ways of varying this delay involve fitting a plurality of connections at fixed input and output electrodes, giving only discrete delay values.

To get continuous delay variation, the invention proposes fitting at least one of the electrode systems, e.g. the output electrode, with at least one moveable part following the longitudinal direction of the piezoelectric element.

Several types of electrode systems are known, and have been used in making delay lines.

A first type, termed "comb in grid," comprises conductor bands or "teeth" placed on one face of the piezoelectric element, perpendicular to the direction of propagation, and interconnected at the ends, generally by two conducting bands parallel to the direction of propagation.

A conducting layer, functioning as a mass electrode, is places on the other face of the piezoelectric element.

A second type, termed "interfingered comb," comprises two grids, each consisting of only one hand parallel to the direction of propagation, mutually imbricated.

The "comb in grid" is less efficient than the "interfingered grid," on the other hand, for a given width of teeth it makes it possible to get a frequency twice that given by the "interfingered grid;" the latter is, moreover, more difficult to construct than the "grid comb" (put out of service when there is a short circuit between adjacent teeth).

French Pat. No. 7,039,960, filed Nov. 6, 1970, in the name of the French Government, represented by the Minister of State responsible for National Defence, Ministerial Delegation for Armaments, Research and Test Methods Department, for;

"Electrode for producing surface mechanical waves on piezoelectric material,"

has described a third type of electrode system.

This third type is characterised by association of a grid comb placed on the piezoelectric element, and an upper electrode placed facing the comb and near it. This upper electrode, by modifying the electric field on the surface, acts as a second interfingered comb grid, whence the name "pseudo-imbricated comb" which has been given to this third type. Its efficiency approaches that of interfingered combs, while having the advantages of grid combs : a short circuit between the teeth does not put the comb out of action ; the maximum working frequency is increased.

According to a preferred way of carrying out the invention, the delay line comprises a fixed comb, preferably one of the three types referred to above, along with a pseudo-imbricated type of comb, whose upper electrode is associated with means of moving it longitudinally, generally parallel to the direction of propagation.

According to a variant, the movable system consists solely of a comb, preferably interfingered, placed on a substrate which is insulating or piezoelectric and near one face of the piezoelectric element, as well as being associated with means of displacement parallel to the direction of propagation.

The invention will be better understood with the assistance of the following description :

In the appended drawing:

FIG. 1 is a top diagrammatic view of a variable delay line in accordance with the preferred mode of executing the invention, and FIG. 2 is a side view of the same.

FIG. 3 shows diagrammatically a particular form of embodiment of the delay line in FIGS. 1 and 2, wherein the plane in which the upper electrode is shifted is inclined in relation to the opposite face of the piezoelectric element.

FIG. 4 is a perspective view of a case containing the different parts of a delay line in accordance with a particular example of embodiment of the device in FIGS. 1 and 2.

FIG. 5 is a diagrammatic side view of the female screw and micrometer male screw drive of the movable electrode of said delay line.

FIG. 6 is a transverse section of the case, at the level of the upper electrode and its drive parts, and FIG. 7 illustrates a modification thereof.

FIGS. 1 and 2 show a piezoelectric element 1 in the shape of a parallelepiped, where the propagation direction Z corresponds to the greatest dimension of this element.

Emitter comb 2, placed on the upper face of one end of element 1 has, by way of example, been shown as an interfingered comb of which each grid comprises two teeth, while the receiver comb is of the pseudo-imbricated type.

It comprises a grid 3 of standard type placed on the upper face of element 1, and an upper electrode 4, consisting of a metal block and shown in FIG. 1 by dot-dash lines, for clarity. In FIG. 1 electrode 4 is prolonged by dashes to show that it can be shifted in direction Z to get continuous variation of the delay.

Earthing electrode 5 completes the device.

Conductors connected to these different electrodes to excite the emitter and collect the current issuing from the receiver are not shown, but it is obvious how they are arranged. Emitter excitation takes place between grids, one of which may be connected to the earthing electrode 5. The output for the receiver is made between 3 and 4, and the movable part 4 may be connected to 5. Earthing electrode 5 can be left out in which case movable part 4 will be put to the hot emitter point of the output amplifier and grid 3 to the case earth of the apparatus.

In the example shown, grid 3 is regular, comprising a large number of teeth, and the distance λ between similar edges of two adjacent teeth of one comb grid emitter is the same as the distance λ between similar edges of two adjacent teeth of grid 3.

However, it is of course to be understood that both the emitter comb and the receiver comb grid can have tooth sizes and numbers, as well as inter-tooth distances, which are different.

Upper electrode 4 is shown flat and rectangular with, to restrict parasitic signals, a width l (perpendicular to the direction of propagation) which is such as not to cover the two connecting bands of grid 3. Preferably its length L is less than or equal to that of the emitter comb.

However, electrode 4 could have different shapes, polygonal or otherwise, and even not be flat (e.g. cylinder element), so as to get an electrical output signal of particular shape.

Since the working of an acoustic delay line is well known, it is sufficient here to indicate that upper electrode 4 captures, through an electrostatic effect, the electric wave formed in grid 3.

FIG. 3 shows the elements of FIG. 2, but with element 1 given a certain slope with respect to the horizontal direction Z' of shift of upper electrode 4. Thus vertical distance h decreases when the electrode moves in the direction of sound propagation.

Because the efficiency of the pseudo-imbricated comb 3–4 increases proportional to the decrease in distance h between electrode 4 and grid 3, the effect of this setup is to compensate for losses due to sound wave propagation, and to make the delay line gain sensibly constant for the entire range of delay values.

FIG. 4 is a diagrammatic picture, with the top off, of a brass box 6, overall outside dimensions 139 × 50 × 50 mm.

Partition 7 divides the lower part of this box into two compartments.

The smaller contains emitter comb electronic emission circuit 8. The larger has the delay line proper, comprising piezoelectric element 11, the comb emitter, which latter is not shown and a movable block 12 carrying upper electrode 13 of the receiver comb. It also includes output amplifier circuit 14 screwed to and thus united to movable block 12. The emitter comb is covered by earthed small brass plate 9. This plate acts as a screen and greatly reduces the amplitude of the parasitic radiation signal.

FIG. 4, left to right, shows:

the connection between circuit 8 and the emitter comb, shown by wire 10 passing through partition 7, from which it is insulated by means of insulating beads ;

Piezoelectric element 11, movable block 12 carrying upper electrode 13 and circuit 14 ;

The electrical connection between upper electrode 13 and output circuit 14 is shown by wire 15. 14 comprises two flexible coaxial wires 16 and 17, connected respectively to two terminals 18 and 19 of the box, one serving to feed the amplifier, the other for its high frequency output. The sheaths of coaxial lines 16 and 17 are earths for the case and circuit 14.

The input terminal of the emitter circuit 8 is shown at 20.

The upper part of case 6 is traversed by micrometer screw 21 controlled by a milled vernier head, now shown. Stop 22 prevents the micrometer screw being withdrawn from the case.

This screw controls the longitudinal translation of a brass female screw 23, prevented from rotating, and made one with block 12. This arrangement gives a total course of 35 mm for electrode 13, the displacement obtained being adjustable to within 10 microns.

A pointer 24 (FIG. 5) integral with female screw 23 can be seen from the outside through a slit made in the removable cover (not shown) of the case. It moves in front of a scale carried by the said cover, showing the value of the delay.

FIG. 5 shows block 12 recessed in the lower part, making a driving guide for female screw 23.

In FIG. 6, the side walls and bottom of the case are seen in transverse section. Piezoelectric element 11 is seen placed in a recess (in the example described this is 1 mm deep), made in the bottom of the case. For example, what is involved is a Y-shaped piece of quartz, 6 cms long, 2 mm thick, 1 cm wide, cemented in the recess with a cellulose varnish, and thus insulated from the case. Movable block 12 is of nylon, and is of T-section, so as to slide in a groove formed, as is seen, by the walls of the case.

Upper electrode 13 is a brass parallelepipedal block, able to slide vertically in a prismatic recess made in block 12. Thus by careful adjustment active face 13a can be brought as close as possible to the piece of quartz. The vertical position of electrode 13 can be fixed by means of locking screw 26. In the example under consideration the dimension *a* (FIG. 6) of this active surface perpendicular to the direction of propagation is 6 mm, while the dimension parallel to the direction of propagation is 4.75 mm.

Further, FIG. 6 shows the drive screw 23 shown in profile, with pointer 24 and one of the two clamping screws 27 which make it possible to take up the play by opening or closing to a greater or lesser extent the jaws formed round the micrometer screw placed in 28.

The delay line just described is of the type shown in FIGS. 1 and 2, i.e. the emitter comb is an interfingered comb deposited on quartz (in the example considered it has 30 pairs of teeth), while the receiver comb is of the pseudo-imbricated type, with a normal grid of about 250 teeth placed on the quartz, and an upper movable electrode 3.

In practice, the emitter comb and the receiver comb brid have been put on the quartz by means of aluminium photo-engraving, using a mask got by photographic reduction of a drawing with the following characteristics;

spacing : 4.8 mm
ratio of tooth width/spacing : ½ for the receiver, ¼ for the emitter
distance between combs : 45 mm
tooth length : 240 mm
receiver comb length : about 120 cm
size of setup : 30 × 150 cm
photographic ratio : 0.0328

Emitter comb emission circuit 8 is made so as to allow the impedance to be adjusted to 50 ohms; e.g. it is made upt of a fixed inductance coil in series with a variable very low capacity condenser (about 10 picofarads), placed in parallel with the capacity of the emitter comb.

The output amplifier 14 is likewise made so as to allow the device to be loaded with an impedance of 50 ohms. This makes it possible to shift, without inconvenience, the wire of output 17, without giving rise to appreciable high frequency radiation. It is to be pointed out that as the quartz crystal is insulated from the case, the receiver comb does not comprise a special earthing electrode; electrode 13 is thus at the voltage hot point, and the corresponding grid placed on the quartz is earthed.

With the non-restricting values indicated above, the delay line has a working frequency of 20.15 Mkc, a 410 kc passing band, 1–12 micro-seconds delay which is quasi linearly variable as a function of the shift of electrode 13, and variable gain 1.20–1.92 depending on the delay (this value takes into account the fact that the se-

lected output amplifier has a gain of 84 at a frequency of 20 Mkc).

The passing band depends particularly on the number of teeth in the emitter comb ; by reducing that number one could get a much broader passing band. However, to achieve a delay line with a wide band, it will be preferably also to modify the receiver comb described, as follows:

The receiver grid engraved on the quartz is eliminated, and the receiver comb is made up solely of a glass tablet on which is deposited by photoengraving, an interfingered comb.

FIG. 7 shows this variant ; tablet 29 whose face 29a, opposite quartz 11, carries the interfingered comb, is glued on brass or nylon cylindrical support 30, sliding in a cylindrical seat made in nylon block 12.

As this seat is cylindrical (and not prismatic as shown in FIG. 6) it is possible to adjust rotation so as to bring the teeth of the receiver interfingered comb parallel to those of the emitter comb. As in the mode of embodiment in FIG. 6, adjustment of the distance between receiver comb and quartz is got by vertical shift of support 30.

Once those adjustments have been made, the said support is glued on its seat.

This variant enables the expensive and difficult operation of engraving a receiver grid on the quartz to be omitted. Moreover it does away with the variation in gain of the line as a function of the delay, and makes possible construction of lines with greater passing bands and smaller delays.

It is obvious that various modifications can be introduced into the systems described and represented, without departing from the sense of the invention.

Depending on the cases of use, the movable electrode will be a receiving or emitting one.

We claim:

1. Delay line comprising an extended piezoelectric element and two input and output electrode systems cooperating with the surface of this element, at least one of the two systems comprising at least one movable part which follows the longitudinal direction of the piezoelectric element, this movable part forming an upper electrode situated close to the active face of the piezoelectric element, wherein one of the two systems of electrodes is a fixed comb deposited on said active face, the other system comprising said upper electrode and a grid comb deposited on said face.

2. Delay line in accordance with claim 1, wherein the upper electrode is flat and rectangular.

3. Delay line in accordance with claim 3, wherein the transverse dimension of said upper electrode is less than the length of the teeth of the associated grid comb, and the longitudinal dimension is less than or equal to that of the other comb.

4. Delay line in accordance with claim 1, wherein the movable part is inclined in relation to the face opposite the piezoelectric element, so that its distance from said face decreases during its longitudinal translation in the direction of propagation of the acoustic waves.

5. Delay line in accordance with claim 1, comprising a case containing the piezoelectric element placed at the bottom, the two systems of electrodes and electronic input and output circuits, the upper electrode being carried by an insulating block controlled, with regard to translation, by a micrometer screw, and sliding in a guide formed by two side walls of the case, wherein the movable electrode is formed on the lower face of a part which can slide, perpendicularly to the face opposite the piezoelectric element, in a recess made in said insulating block, which is itself integral with a female screw whose rotation is blocked on the micrometer screw.

6. Delay line in accordance with claim 5, wherein said piece is cylindrical, and capable of being adjusted by rotation in the said recess.

7. Delay line in accordance with claim 1, wherein said fixed comb is covered by an earthed conducting screen.

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