

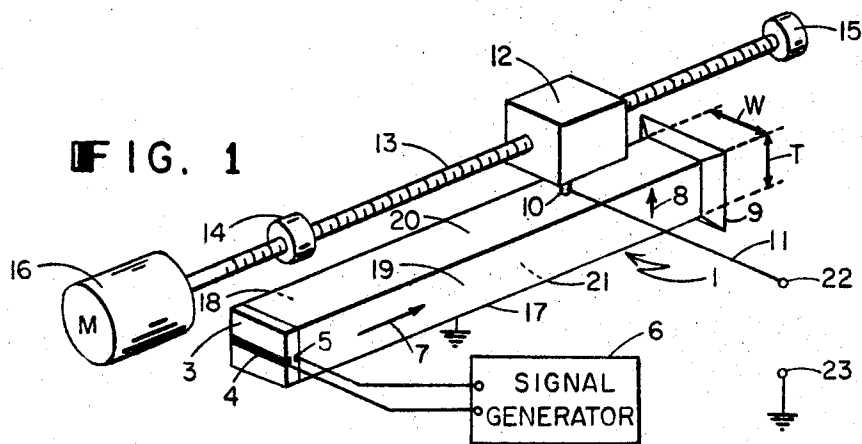
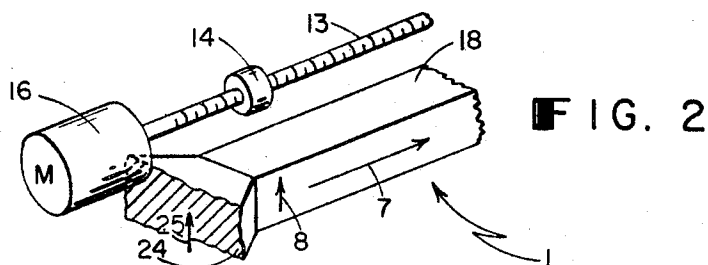
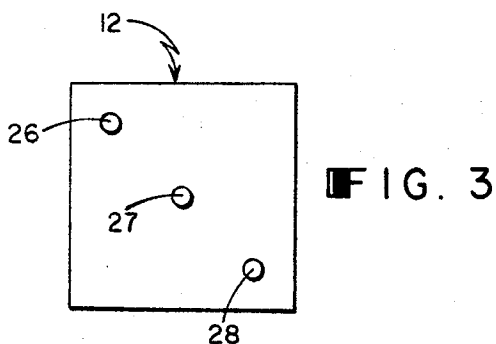
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R. M. ZILBERSTEIN

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VARIABLE DELAY LINE WITH MOVABLE ELECTRODE

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INVENTOR.
R. MICHEL ZILBERSTEIN

BY *Richard M. Jennings*
ATTORNEY.

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VARIABLE DELAY LINE WITH MOVABLE ELECTRODE

Raoul Michel Zilberstein, Sharon, Mass., assignor to Laboratory for Electronics, Inc., Boston, Mass., a corporation of Delaware

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11 Claims

This invention relates in general to ultrasonic delay lines and more particularly to variable solid delay lines.

Variable delay lines, both liquid and solid, are widely used throughout the industry. In the past the time of delay was varied, generally, by adjusting the length of the path the acoustic wave traveled in an homogenous acoustic medium. This variance in acoustic path length has been attained by numerous devices. For example, one type comprises a pair of elongated pieces of fused quartz disposed side by side in a moveable relationship and in contact with one another. An input transducer, such as a piezoelectric crystal, is intimately attached to one end of the first elongated piece, while a similar output transducer is connected to the opposite end of the second piece. The length of the delay path is varied by virtue of sliding the two elongated pieces with respect to each other to thereby adjust the distance between the input and output transducers. Another solid variable line, commonly known as the double-rail delay, comprises a pair of elongated pieces of fused quartz disposed parallel to each other and spaced apart a predetermined distance. An input transducer is attached to one end of the first elongated piece while an output transducer is attached to the second piece, but at the same end as the input transducer. A polygonal shaped slider block formed from a piece of fused quartz cooperates with the top edge of each elongated piece to interconnect the two pieces. The acoustic wave propagates down the first elongated piece, through the polygonal shaped slider block into the second elongated piece, and then to the output transducer. Thus, the delay path may be varied by sliding the polygonal block along the edges of the two elongated fused quartz pieces to effectively adjust the distance between the input and output transducers. Still another solid variable line takes the form of an elongated acoustic medium divided into three distinct portions, with the middle portion being shaped like an isosceles triangle. The triangular portion is moveable in a direction perpendicular to the direction of wave propagation while one of the other portions, preferably the portion connected to an output transducer, is simultaneously moveable in a direction parallel to the direction of wave propagation so as to maintain contact with one edge of the triangular portion at all times. It follows that by adjusting the position of the triangular portion the distance between the input and output transducer is also adjusted to provide a variable delay.

From the above discussion it is apparent that presently employed solid variable delay lines require sliding contact between, relatively speaking, large surface areas of either portions of the delay line itself or a slider block and the primary delay medium. This in turn dictates the use of a lubricant to support the sliding movement between these surfaces. Inasmuch as the propagating acoustic wave must pass through the moving, as well as the fixed, portion of the delay apparatus, the lubricant must be of a special type so as to support acoustic wave propagation. Not only are these special lubricants disadvantageous from an expense standpoint, but more importantly, even the most advanced types greatly attenuate the propagated acoustic wave. Moreover, the moveable portion of the delay apparatus must be constructed from the same type and quality of material as the fixed portion and disposed

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to cooperate with the latter in a predetermined fashion, which is a difficult design problem at best. In addition, reflections of the acoustic wave at the interface between the moveable and fixed portions of the material result in spurious signals contributing still further to the total degradation of the resultant delayed signal. As if the above limitations are not enough, many of the known variable delay lines require specially constructed input and output transducers which add to the amount of insertion loss. It will be appreciated from the above that the scope of application of currently known solid variable delay lines is strictly limited.

Accordingly, a primary object of the present invention is the provision of a simple, rugged and economical variable solid delay line.

Another object is a variable solid delay line which eliminates the requirement of a lubricant between the moveable electrode and the delay medium.

A further object is the provision of a solid variable delay line having a wide band frequency response.

Still a further object is the provision of a variable solid delay line wherein the delay medium acts as its own transducer.

Another object of the present invention is the provision of a variable solid delay line using conventional piezoelectric input transducers.

Another object is the provision of a moveable electrode having a minimum contact area.

Briefly speaking, the present invention contemplates a continuously variable solid ultrasonic delay line having a wide band frequency response, employing conventional input and output transducers, and generally, exhibiting the same characteristics as a comparable fixed delay line. To this end, there is provided in the preferred embodiment an elongated acoustic-wave propagating medium preferably shaped in the form of a rectangular bar and composed of a material having piezoelectric properties. An input transducer, such as a piezoelectric ceramic, is attached to one end of the acoustic medium to impress an acoustic wave upon the medium in response to an electrical signal. A pair of pickoff electrodes are disposed on opposite faces of the acoustic medium to sense the acoustic wave propagating therethrough. At least one of the electrodes is connected to a slider block which in turn is driven by a screw drive so as to adjustably position the pickoff electrode at selected points along the acoustic medium. Since the acoustic medium is formed from a material having piezoelectric characteristics, the wave-front of the acoustic wave sets up disturbances in the form of potential differences on opposite faces of the medium as the acoustic wave propagates therethrough. That is, in effect, the acoustic wave propagating medium acts as its own transducer. The resultant potential differences are sensed by the pickoff electrodes to provide an output signal. Inasmuch as at least one of the pickoff electrodes is moveable along a face of the acoustic medium in a direction parallel to the direction of wave propagation, the amount of delay may be adjustably varied without changing the length of the acoustic wave path.

The above and other objects and features of this invention will become apparent from the following detailed description when read in conjunction with the accompanying drawing in which:

FIG. 1 is a perspective view of the preferred embodiment of the solid variable delay line in accordance with the present invention;

FIG. 2 is a diagrammatic view of an alternative embodiment wherein the variable delay line is affixed to the output of a conventional fused quartz fixed delay line; and

FIG. 3 is a bottom view of the slider block showing an alternate arrangement of pickoff electrodes thereon.

With respect now to the drawing and in particular FIG. 1 thereof, it will be observed that the solid variable delay line, in accordance with the present invention, comprises an elongated acoustic wave propagating medium 1 formed of crystalline quartz, barium titanate, lead zirconate titanate, sodium potassium or lead metaniobate or any other material naturally having or polarized to exhibit piezoelectric properties. The acoustic medium is preferably shaped in the form of a rectangular bar having opposed parallel faces 18, 19 and 20 and 21. The dimensions of the rectangular bar, namely, the width W and thickness T, are both many wavelengths, on the order of ten times the mean frequency of the applied signal so as to propagate an acoustic wave with a minimum of distortion. Of course, the length of the line is dictated by the maximum amount delay desired. The elongated medium is polarized in the thickness direction T, as represented by the arrow 8, to provide potential differences on the top and bottom faces 20 and 21, respectively, in response to a propagating acoustic shear wave.

An input transducer 3, such as a piezoelectric crystal, is intimately attached to the end of elongated acoustic wave medium 1 by means of a suitable bonding agent and operates to impress upon or couple an acoustic wave to the elongated medium 1 in response to an applied electrical signal. The bond, by way of example, may be indium, epoxy, ceramic or any other bonding agent well known in the art which provides a proper impedance match for maximum signal coupling between the transducer 3 and acoustic medium 1. A pair of electrodes 4 and 5 are transversely disposed across the width and fused to opposite sides of transducer 13 to apply the electrical signal generated by signal generator 6 to input transducer 13. The input transducer is orientated in such a manner as to set up plane shear waves in the thickness direction of the acoustic medium 1 in response to the applied electrical signal.

At the opposite end of elongated acoustic medium 1 there is attached by way of a suitable bonding agent a flare shaped lossy termination 9 to absorb the propagating acoustic wave energy so as to prevent end reflections of the wave back through the medium. Of course, it is apparent that, if a signal output at this point is desired, lossy termination 9 may be replaced with an output transducer to reconvert the acoustic wave into an electrical signal.

A slider block 12, which may be, by way of example, a rectangular block of plastic or any other well known insulating material, is disposed with its bottom face parallel to and spaced a predetermined distance from the top face 20 of acoustic wave propagating medium 1. Slider block 12 is keyed to screw drive 13 which in turn is journaled in bearings 14 and 15. The motor 16 is coupled through appropriate gearing (not shown) to one end of screw drive 13 to rotate the latter in response to an input signal.

A pickoff electrode 10 comprising a fabricated metallic contact approximately one inch wide is mounted on the bottom face of slider block 12 and is adapted to cooperate with the top face 20 of elongated acoustic wave medium 1 to sense the wave propagating therethrough in a manner described hereinafter. The electrode is curved at the point of slideable contact with the acoustic wave medium 1 to thereby provide, relatively speaking, a minute interface contact surface area. In practice the width of the contact electrode is approximately a wavelength or less of the mean input signal frequency so as to provide maximum signal detection with minimal distortion.

The bottom face 21 of elongated acoustic medium 1 is coated with a silver paint and connected to ground to provide a second electrode 17. Output terminals 22 and 23 are connected by means of appropriate wires to electrodes 10 and 17, respectively, to derive an output representative of the delayed signal.

In operation an electrical signal derived from signal generator 6 is converted into an acoustic wave and coupled to propagating medium 1 by means of piezoelectric input transducer 3. The electrical signal may be either modulated RF or a digital signal. As discussed in the foregoing, input transducer 3 is orientated to set up mechanical vibrations in the thickness shear mode in response to an electrical signal. Accordingly, transducer 3 responds to the input signal to impress a shear wave in the thickness direction T upon the acoustic medium 1 which propagates through the medium in the direction of arrow 7. As the acoustic shear wave travels through acoustic medium 1, the wave front sets up disturbances on the two opposed parallel faces 20 and 21. Since the acoustic medium is composed of an homogeneous material having piezoelectric properties, these disturbances take the form of potential differences. That is to say, in effect, the acoustic medium acts as its own output transducer. The resultant potential differences are in turn sensed by electrodes 10 and 17 to produce an electrical signal representative of the acoustic wave being transmitted by the acoustic medium. It is significant to note at this point that acoustic medium 1 is polarized in the thickness direction T parallel to the direction of the shear wave while the electrodes 10 and 17 are located on faces that are perpendicular to the direction of the shear wave.

The delay time may be varied as desired by adjusting the position of moveable electrode 10 along the direction of propagation. For example, when screw drive 13 rotates in the appropriate direction to move slider block 12 toward input transducer 3, the delay is shortened, while, when slider block 12 is moved in the opposite direction, the delay time increases.

The embodiment shown in FIG. 2 is similar to that shown in FIG. 1 and, accordingly, elements in FIG. 2 which correspond to those shown in FIG. 1 are identified by like reference numerals. In this embodiment, however, the input transducer 3 has been replaced by a fused quartz delay line, of which, for the purposes of clarity, only a portion thereof is illustrated. That is, the input end of acoustic medium 1 is affixed to one facet of the fused quartz delay line 24 by means of a suitable bonding agent which provides maximum coupling of the acoustic wave. Of course, in the illustrated embodiment the acoustic wave transmitted by the fused quartz medium must be a plane shear wave in the direction of arrow 25. By virtue of sliding electrode 10 along the face 20 of acoustic medium 1, the total delay time can be set to a high degree of precision.

FIG. 3 shows a bottom view of an alternate embodiment of the slider block which may be used with the solid variable delay line in accordance with the principles of the invention. A plurality of electrodes 26, 27 and 28 are equally spaced and arranged diagonally across the bottom face of the slider block 12. In this manner a plurality of unequally delayed signal outputs, each being variable by adjusting the position of the slider block 12, may be simultaneously produced.

From the foregoing description it will be apparent to those skilled in the art that numerous variations and departures may be made from the specific disclosed embodiment without departing from the inventive concepts disclosed herein. For instance, if desired, fixed electrode 17 may be replaced by a point electrode, similar to moveable electrode 10, disposed opposite moveable electrode 10 and adapted to slideably move along the bottom face of acoustic medium 1 in tandem with moveable electrode 10. Furthermore, the acoustic medium may be adapted to support a propagating shear wave in the width direction in which case the pickoff electrodes would be positioned on the opposite side faces of acoustic medium 1. Also, in place of moveable electrodes or in addition thereto, fixed point electrodes may be bonded at selected positions along the faces of the acoustic medium to pro-

vide a tapped delay line. Consequently, the invention is to be construed as limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A variable delay line comprising: an acoustic wave propagating medium having piezoelectric properties; means to couple an acoustic wave to said propagating medium; and, a pair of electrodes cooperating with said medium to sense the acoustic wave propagating therein, at least one of said electrodes being moveable with respect to said acoustic wave propagating medium to provide an adjustable delay time.

2. A variable solid delay line comprising: an elongated acoustic medium having a set of opposed faces; said acoustic medium exhibiting piezoelectric properties; a coupling means to impress an acoustic wave upon said acoustic medium; and, a pair of electrodes disposed on the opposite faces of said acoustic medium to sense the acoustic wave propagating therein, at least one of said electrodes being slideably moveable along a face of said acoustic medium to adjust the time of delay provided by said medium.

3. A variable delay line as claimed in claim 2 wherein said acoustic medium is adapted to support an acoustic shear wave and said coupling means responds to an applied electrical signal to set up mechanical vibrations in the shear direction.

4. A variable delay line as claimed in claim 3 wherein said coupling means comprises an input transducer connected to said acoustic medium to impress an acoustic shear wave thereon in response to an applied electrical signal.

5. A variable delay line as claimed in claim 4 wherein said elongated acoustic medium is formed in the shape of a rectangular bar moving a pair of opposed parallel faces, each face lying in a plane perpendicular to the direction of shear.

6. A variable delay line as claimed in claim 3 wherein said coupling means comprises a fused quartz delay line having a plurality of facets, one of said facets connected to an end of said acoustic medium.

7. A variable delay line as claimed in claim 3 comprising

ing in addition a slider block having one of said pair of pickoff electrodes attached thereto, and means to move said slider block in a direction parallel to the direction of propagation of the acoustic wave to adjust the time of delay provided by the acoustic medium.

8. A variable delay line as claimed in claim 7 wherein a plurality of pickoff electrodes are connected to and disposed diagonally across a face of said slider block.

9. A variable delay line as claimed in claim 7 wherein the other of said pair of pickoff electrodes comprises a metallic coating disposed on one face of said acoustic medium.

10. A variable ultrasonic delay line comprising: an elongated solid acoustic wave propagating medium having a pair of opposed faces, said acoustic medium exhibiting piezoelectric properties; an input transducer connected to said acoustic medium to impress a shear wave thereon in response to an electrical signal; a pair of electrodes disposed on the opposite faces of said acoustic medium to sense the shear wave propagating there-through; and, means to slideably move at least one of said electrodes along the face of said acoustic medium in a direction parallel to the direction of propagation of the acoustic wave to adjust the amount of delay offered by the acoustic medium.

11. A variable delay line comprising: a solid elongated acoustic wave propagating medium having piezoelectric properties; means to impress an acoustic shear wave upon said medium; and, electrode means cooperating with said medium to sense the acoustic wave propagating therein, said electrode means being moveable in a direction parallel to the direction of acoustic wave propagation to adjust the amount of delay offered by the acoustic medium.

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D. R. HOSTETTER, *Assistant Examiner.*