



PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Ultrasonic Delay Lines

We, WESTERN ELECTRIC COMPANY, INCORPORATED, of 195 Broadway, New York City, New York State, United States of America, a Corporation of the State of New York, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to delay lines and more particularly to ultrasonic delay lines of compact and space-saving physical configuration.

The value of several forms of ultrasonic delay lines for use in pulse systems is being increasingly appreciated, and new applications for these lines are regularly being proposed. However, one serious limitation upon their usefulness is their physical size and general physical awkwardness. These limitations are particularly critical in applications such as large capacity memories where many delay lines must be assembled to store the desired amount of information.

One of the preferred types of delay lines from this standpoint is the strip delay line which takes the form of a long, wide, thin strip capable of being coiled into a spiral, and capable of being operated in several different modes of vibration. Such a line is disclosed in United States of America patent 3,041,556, granted June 26, 1962. While having considerable advantage over other types which must be held straight, rigid, or under tension, the spiral strip delay line still requires considerable space and one transducer must be inconveniently located at the centre of the spiral.

According to the present invention a delay line comprises an elongated thin strip of ultrasonic transmission material, the said strip having a 180 degree bend at a point between its ends and having at least a portion of itself wound bifilarly about the said bend, and transducer means mounted on each of the said ends for generating and responding respectively to

thickness shear modes of elastic wave motion in the strip.

In a preferred embodiment of the invention the strip is of rectangular cross-section and has the width dimension many times that of the thickness dimension. Thickness-shear mode transducers are mounted on each end of such a strip for generating and responding to elastic shear wave motion in the strip and the strip has a sharp 180 degree bend parallel to the said wave motion. Such a delay line is found to have the property that the thickness shear mode of propagation can traverse the sharp bend with substantially no attenuation or mode degeneration. This property, which appears to be unique for this mode among all other modes of elastic vibration, makes it possible to construct a delay line by folding or bending the strip at a point substantially midway along its length and rolling it bifilarly about the bend into a tight compact roll. The transducers mounted on each end of the strip will then appear upon the circumference of the roll thereby providing easy access for connection and repair.

An embodiment of the invention will now be described with reference to the accompanying drawing in which:—

Fig. 1 is a perspective view of a delay line system in accordance with the present invention; and

Fig. 2 is an enlarged fragmentary view of the delay line of Fig. 1 in an uncoiled condition in order to show details of the transducers.

Referring more particularly to Fig. 1, an illustrative embodiment comprises a strip of delay material 11 having a width dimension w that is substantially greater than its thickness dimension t . The line may be formed of any nonbrittle, isotropic material such as aluminium or of a polycrystalline metallic alloy provided the grain size of the alloy is small compared with the wavelength of the elastic wave motion to be conducted by the strip. Strip 11 is bent back upon itself sharply about its width

dimension at a point 12 approximately in the centre of its length. Bend 12 may be crimped tightly with a vice or pliers to produce a complete 180 degree curve. Strip 11 is then rolled tightly in a bifilar manner starting with bend 12 at the centre of the spiral and continuing back toward the two ends to constitute a compact package. The roll may then be rigidly mounted by any suitable means which contacts only the narrow or minor edges of strip 11 since these edges are dead surfaces. As illustrated, suitable mounting means may comprise a baseboard 13 and an offset bracket or clamp 14. Transducers 15 are bonded to the face of each end of strip 11 by conventional techniques. A particular feature of the invention is that both transducers are located upon the outer region of the delay line coil. A pair of wires 16 is connected to each of the transducers which may be used interchangeably as output and input transducers, respectively.

Fig. 2 shows an enlarged fragmentary view of strip 11 in an uncoiled condition from which the sharpness of bend 12 may be clearly seen and the details of the transducer may be examined. Thus, each of the transducers 15 may be of one of the several designs known to produce a thickness-shear mode of elastic vibration on strip 11. For example they may each be Y-cut piezoelectric crystals or may each be thickness-shear mode BaTiO₃ ceramic transducers appropriately bonded to the end faces 17 of strip 11. In either case the transducers are properly poled as represented by arrows 18 in a direction perpendicular to the length axis of strip 11 and parallel to the major surfaces thereof. Such a transducer produces a thickness shear mode of wave motion in strip 11, that is, one for which each particle 19 moves perpendicular to the length axis and parallel to the direction of poling in the transducer.

Reflections of wave motion from the minor surfaces of strip 11 and cross coupling between adjacent turns of the spiral would produce undesirable interactions. This is prevented by coating or covering the minor surfaces as well as the immediately adjacent edges of the major surfaces of strip 11 with absorber 20 which may take the form of a cloth or plastic-backed adhesive tape folded over the edges of strip 11.

The thickness-shear mode, and only this mode of vibration, can negotiate bend 12 without either mode degeneration or energy loss. In addition, no energy is

lost or mode conversion takes place as a result of reflections from the major surfaces. A possible explanation of both effects resides in the fact that particle motion for this mode of vibration is in a direction parallel to the major surfaces and parallel to the line of the bend so that the major surfaces guide the wave motion around the bend with no reflection or energy loss. Thus wave energy launched by one transducer travels the spiral curve into the centre of the coil, negotiates bend 12 and returns on the interleaved turns of the spiral to the other transducer wherein the shear vibration is converted into electrical energy.

WHAT WE CLAIM IS:—

1. A delay line comprising an elongated thin strip of ultrasonic transmission material, the said strip having a 180 degree bend at a point between its ends and having at least a portion of itself wound bifilarly about the said bend, and transducer means mounted on each of the said ends for generating and responding respectively to thickness shear modes of elastic wave motion in the strip.

2. A delay line comprising an elongated thin strip of ultrasonic transmission material and transducer means mounted on each end of the said strip for generating and responding respectively to elastic shear wave motion in the said strip, the said strip having a 180 degree bend parallel to the said wave motion at a point between its ends and having at least a portion of itself wound bifilarly about the said bend toward the said ends.

3. A delay line comprising an elongated thin strip of ultrasonic transmission material and thickness-shear mode transducer means mounted on each end of the said strip for generating and responding respectively to elastic shear wave motion in the said strip, the said strip having a rectangular cross-section with a width dimension many times that of the thickness dimension and 180 degree bend parallel to the said wave motion at a point substantially midway between its ends, the said strip being wound bifilarly about the said bend towards the said ends.

4. A delay line substantially as hereinbefore described with reference to and as shown in Figs. 1 and 2 of the accompanying drawing.

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dimension at a point 12 approximately in the centre of its length. Bend 12 may be crimped tightly with a vice or pliers to produce a complete 180 degree curve. Strip 11 is then rolled tightly in a bifilar manner starting with bend 12 at the centre of the spiral and continuing back toward the two ends to constitute a compact package. The roll may then be rigidly mounted by any suitable means which contacts only the narrow or minor edges of strip 11 since these edges are dead surfaces. As illustrated, suitable mounting means may comprise a baseboard 13 and an offset bracket or clamp 14. Transducers 15 are bonded to the face of each end of strip 11 by conventional techniques. A particular feature of the invention is that both transducers are located upon the outer region of the delay line coil. A pair of wires 16 is connected to each of the transducers which may be used interchangeably as output and input transducers, respectively.

Fig. 2 shows an enlarged fragmentary view of strip 11 in an uncoiled condition from which the sharpness of bend 12 may be clearly seen and the details of the transducer may be examined. Thus, each of the transducers 15 may be of one of the several designs known to produce a thickness-shear mode of elastic vibration on strip 11. For example they may each be Y-cut piezoelectric crystals or may each be thickness-shear mode BaTiO₃ ceramic transducers appropriately bonded to the end faces 17 of strip 11. In either case the transducers are properly poled as represented by arrows 18 in a direction perpendicular to the length axis of strip 11 and parallel to the major surfaces thereof. Such a transducer produces a thickness shear mode of wave motion in strip 11, that is, one for which each particle 19 moves perpendicular to the length axis and parallel to the direction of poling in the transducer.

Reflections of wave motion from the minor surfaces of strip 11 and cross coupling between adjacent turns of the spiral would produce undesirable interactions. This is prevented by coating or covering the minor surfaces as well as the immediately adjacent edges of the major surfaces of strip 11 with absorber 20 which may take the form of a cloth or plastic-backed adhesive tape folded over the edges of strip 11.

The thickness-shear mode, and only this mode of vibration, can negotiate bend 12 without either mode degeneration or energy loss. In addition, no energy is

lost or mode conversion takes place as a result of reflections from the major surfaces. A possible explanation of both effects resides in the fact that particle motion for this mode of vibration is in a direction parallel to the major surfaces and parallel to the line of the bend so that the major surfaces guide the wave motion around the bend with no reflection or energy loss. Thus wave energy launched by one transducer travels the spiral curve into the centre of the coil, negotiates bend 12 and returns on the interleaved turns of the spiral to the other transducer wherein the shear vibration is converted into electrical energy.

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1. A delay line comprising an elongated thin strip of ultrasonic transmission material, the said strip having a 180 degree bend at a point between its ends and having at least a portion of itself wound bifilarly about the said bend, and transducer means mounted on each of the said ends for generating and responding respectively to thickness shear modes of elastic wave motion in the strip.

2. A delay line comprising an elongated thin strip of ultrasonic transmission material and transducer means mounted on each end of the said strip for generating and responding respectively to elastic shear wave motion in the said strip, the said strip having a 180 degree bend parallel to the said wave motion at a point between its ends and having at least a portion of itself wound bifilarly about the said bend toward the said ends.

3. A delay line comprising an elongated thin strip of ultrasonic transmission material and thickness-shear mode transducer means mounted on each end of the said strip for generating and responding respectively to elastic shear wave motion in the said strip, the said strip having a rectangular cross-section with a width dimension many times that of the thickness dimension and 180 degree bend parallel to the said wave motion at a point substantially midway between its ends, the said strip being wound bifilarly about the said bend towards the said ends.

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