Dec. 13, 1966 S. K. HSU ETAL 3,292,019

TRANSDUCER

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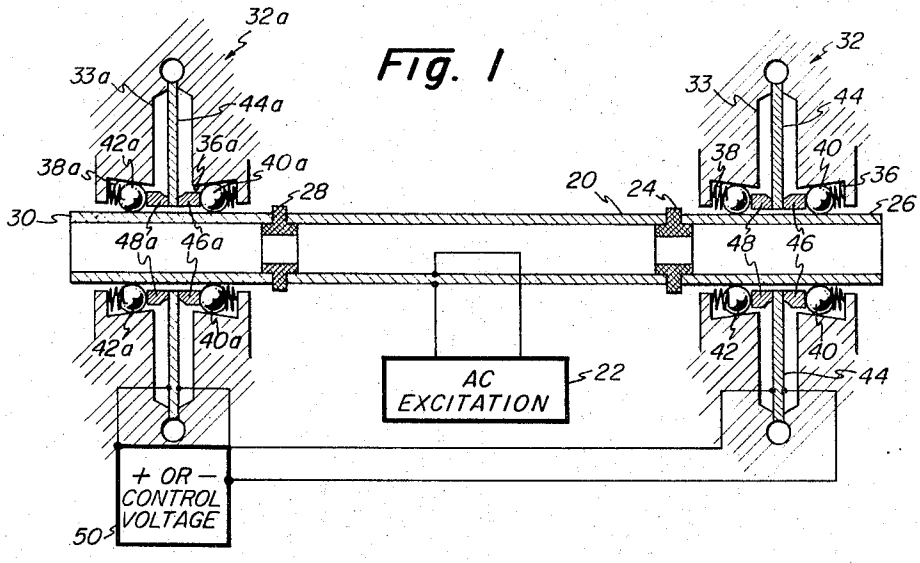
Fig. 1



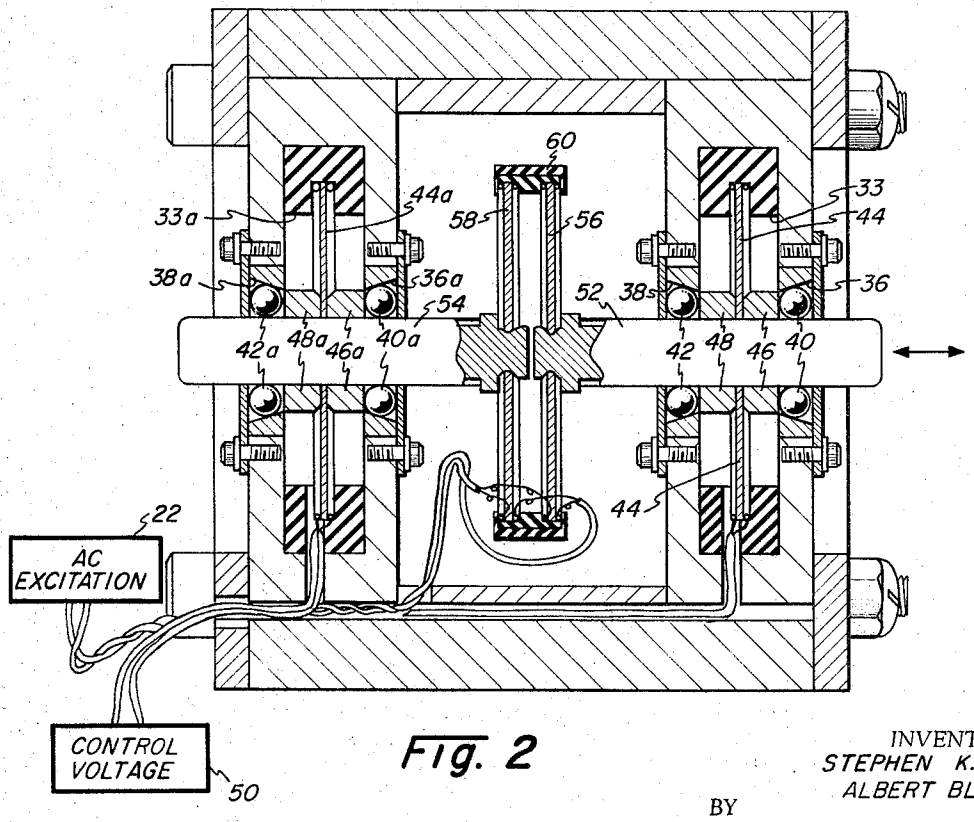


Fig. 2

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This invention pertains to a transducer of a kind which receives an electrical signal and provides a very accurate minute mechanical movement which is especially suitable for servo actuator use. More particularly this invention pertains to a transducer utilizing a piezoelectric member for translating electrical signals to small mechanical movements in combination with two one-way clamps which accumulate the movements of the piezoelectric member in one direction at a time.

It is an important object of this invention to provide a transducer for receiving electrical signals and changing them into very small and very accurate movements through the use of a piezoelectric member to which an alternating voltage potential is applied; and in combination with a pair of one-way clamps that permit the oscillatory motion of the piezoelectric member to accumulate in one direction only.

It is an object of this invention to provide in a transducer of the previous paragraph means for reversing the one-way clamps so that direction of the piezoelectric member may also be accumulated in the opposite direction.

It is a further object of this invention to provide in such a transducer a piezoelectric member which has applied thereto an alternating voltage potential causing an oscillatory motion of the piezoelectric member with a one-way clamp on either side of the expansion and contraction due to the oscillatory motion so that the expansion is permitted in one direction only due to clamping one end of the oscillating member, and the contraction also results in movement in the same direction due to clamping the other end of the oscillatory member.

It is a further object of this invention to utilize as the piezoelectric member of the previous paragraph two piezoelectric discs which have their axis aligned with the direction of moveemnt and are securely connected to one another at their circumferences; the deflection "polarity" of the discs is such that when a shaft is connected centrally to each disc, application of a voltage of one polarity to the discs will cause both of them to curve outwardly forcing the two shafts apart and application of a voltage of the opposite polarity to the discs will cause both of them to bend inwardly towards each other bringing the two shafts towards each other.

It is another object of this invention to provide as the one-way clamping means two annular wedge surfaces which are inclined to the shaft axis such that when wedged members are placed between the shaft and the wedge surfaces, the shaft will be prevented from movement in either direction, when the wedged members associated with one surface are released, the shaft can move in the one direction, and when the wedged members in the other surface are released, it will allow the shaft to move in the opposite direction; and a piezoelectric disc having an opening centrally thereof on each side of which is attached a sleeve member with the first sleeve member engageable with the wedged members associated with the one wedge surface upon movement of the piezoelectric disc in one direction and the second sleeve engageable with the wedged members of the other surface movement of the piezoelectric disc in the other direction thereby releasing the wedge members which are

engaged by their corresponding sleeve providing for bidirectional movement of the shaft.

These and other objects and advantages will become apparent when preferred embodiments are discussed in connection with the drawings in which:

FIGURE 1 is a sectional view of a preferred embodiment; and

FIGURE 2 is a sectional view of a second preferred embodiment.

In FIGURE 1 is a piezoelectric tube **20** of electrical potential responsive materials such as lead zirconate titanate so that upon application of an electrical field by an alternating voltage source **22**, the tube **20** will expand and contract radially and axially an amount which is dependent upon the materials used and the tube dimensions as is well known in the art. On each cycle of alternating voltage excitation, the tube expands and contracts once.

At one end of tube **20** is a connector **24** for connecting a shaft extension **26** and at the other end of tube **20** is a connecter **28** for connecting a shaft extension **30**. It is noted that connectors **24** and **28** have circumferential extensions which also serve as travel limiters in this embodiment.

One-way clamps shown generally by arrows **32** and **32***a* are located about shaft extensions **26** and **30** respectively and are for the purpose of permitting movement of the respective shaft extensions in one direction only, and this direction is selectively to the right or left as will be subsequently explained.

The construction of the clamps **32**, **32***a* is identical and therefore only clamp **32** will be explained in detail. The corresponding parts of clamp **32***a* will carry the same reference numeral suffixed with an "*a*." In clamp **32** is a pair of annular wedge surfaces **36**, **38** which are concentric with shaft extension **26**. Located between shaft extension **26** and wedge surface **36** is a plurality of wedge members or balls **40** which as shown are spring urged to the left which prevent movement of shaft extension **26** to the left. Located between wedge surface **28** and shaft extension **26** are a purality of wedge members or balls **42**, which are spring urged to the right which prevent movement of shaft extension **26** to the right so that shaft extension **26** will be retarded from leftward movement by the wedging action of balls **40** and will be retarded from rightward movement by the wedging action of balls **42**.

The means in which to release balls **40** and **42** from their wedging action will now be discussed. A piezoelectric disc **44** is secured at its outer circumference to the clamp housing **33** and has a central opening about which is attached a par of sleeves **46** and **48**. The piezoelectric discs may be comprised of two thin layers of piezoelectric ceramics, such as lead zirconate titanate, which are electrically poled in opposite directions and which have an electrically conductive vane sandwiched in-between. A thin layer of silver may be on the outer sides of each of the ceramic layers. A direct current voltage control source **50** is electrically connected to the piezoelectric member **44** which is a piezoelectric bender disc. Upon application of voltage in one direction, the disc **44** will be moved to the right resulting in sleeve **46** forcing balls **40** away from the wedging action thereby permitting movement of shaft extension **26** only to the left. When the control voltage from source **50** is reversed, the disc **44** will move to the left at which time sleeve **48** will engage the balls **42** moving them to a release position against the action of the springs so that shaft extension **26** can move only to the right. As mentioned, clamp assembly **32***a* is identical and it is also connected to control voltage **50** and the corresponding disc **44***a* moves in the same direction as disc **44**.

Operation

Assume that the direction of control voltage from source **50** moves piezoelectric discs **44** and **44***a* to the right. This permits shaft extensions **26** and **30** to move to the left upon expansion and contraction by piezoelectric tube **20**. On an expansion of piezoelectric tube **20**, the wedging action of balls **42** will prevent tube extension **26** from moving to the right while extension **30** is free to move to the left since the wedging action of balls **40***a* is prevented by the sleeve **46***a* having moved them against the spring pressure to the right. As the tube **20** contracts due to a reversal in the A.C. excitation, the wedging action of balls **42***a* will prevent rightward movement of shaft extension **30** while shaft extension **26** is free to move in a leftwardly direction since the wedging action of balls **40** will not take place since sleeve **46** urges the balls **40** against their spring to the right. This results in a pulsating or incremental move of the shaft or tube **20** to the left every time there is a reversal of A.C. excitation and, the higher the frequency of the A.C. excitation, the faster will be the movement in the leftward direction.

In order to provide movement of the right, the polarity of voltage source **50** is simply reversed swinging piezoelectric discs **44** and **44***a* to the left providing for a rightward movement of tube **20**.

The embodiment of FIGURE 2

The construction and operation of the embodiment of FIGURE 2 is similar to that of FIGURE 1 in all essential respects except for the design of the oscillating piezoelectric member which moves shafts **52** and **54**. In this embodiment, there are a pair of piezoelectric discs **56** and **58**, each similar to disc **44**, which are spaced apart and secured in this spaced apart relation at their outer circumference by collar **60**. The discs **56** and **58** have like polarity facing each other so that upon A.C. excitation, disc **56** will curve in the opposite direction of disc **58**. For example, during one portion of the A.C. excitation cycle both discs **56** and **58** will curve outwardly so that shaft **52** will be separated from shaft **54** while in the reverse cycle of A.C. excitation, disc **56** and disc **58** will curve inwardly bringing shafts **52** and **54** closer together. The one-way clamps in this embodiment are similar in operation and construction to those in the embodiment of FIGURE 1 and are similarly numbered.

In one test model similar to that in FIGURE 2, at 110 volts and 60 cycles per second A.C., the shafts **52** and **54** move about one-quarter inch per second while at 400 cycles per second A.C. they move about six times as fast. The embodiment of FIGURE 2 operates at a relatively high stroking rate compared with that of the embodiment of FIGURE 1.

The piezoelectric members used in the preferred embodiment are comprised of two ceramic layers of lead zirconate titanate each about .020 inch in thickness and separated by a brass layer of .002 inch thickness with a .002 inch silver plate being on the outside surface of each of the ceramic layers.

Although this invention has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

Having thus described our invention, we claim:

1. A transducer for changing an electrical signal into minute corresponding movements of an output member comprising,

electrical strain producing means,

said electrical strain producing means experiencing and contraction which is proportional to the magnitude of input signals being applied thereto,

directional clamp means in clampable relation to said strain producing means to provide freedom of movement of said electrical strain producing means in one direction during said expansion and contraction and restrict movement in another direction during said expansion and contraction.

2. A transducer for changing an electrical signal into minute corresponding movements of an output member comprising,

an electrical strain producing means having a longitudinal axis,

said electrical strain producing means experiencing longitudinal expansion and contraction in proportion to input signals applied thereto,

directional clamp means in clampable relation to said strain producing means at longitudinally spaced points to provide freedom of movement in one direction along the longitudinal dimension at one of said points and restriction of movement in the opposite direction at the other of said points during an expansion thereby providing an increment of movement in said one direction of said electrical strain producing means, and to provide freedom of movement at the other of said points in said one direction and restriction of movement in the opposite direction at said one point during a contraction of said electrical strain producing means, thereby producing an increment of movement of said electrical strain producing means in said one direction.

3. The transducer of claim **2** with said directional clamp means being reversible.

4. The transducer of claim **2** with said electrical strain producing means being a piezoelectric tube.

5. The transducer of claim **2** with said electrical strain producing means comprising a pair of axially aligned rigid shafts,

a pair of piezoelectric discs being connected to one another at their circumferences so that disc surfaces facing each other have like electrical polarity and application of electrical energy to the pair of discs will cause the discs to curve outwardly away from one another at the same time and then inwardly toward one another at the same time,

one of said discs being connected at its center to one of said shafts and the other of said discs being connected at its center to the other of said shafts.

6. The transducer of claim **2** with said directional clamp means comprising longitudinally spaced clamp assemblies,

each clamp assembly comprising a pair of longitudinally spaced annular wedge surfaces,

said electrical strain producing means extending through said spaced annular wedge surfaces,

a series of wedge members being between each wedge surface and said shaft,

means to urge said wedge members to a wedging position,

said wedge surfaces in each clamp assembly being inclined to the electrical strain producing means axis so that the wedging action of the wedge members between one wedge surface and the strain producing means prevents movement of the strain producing means in one direction and the wedging action of the wedge members between the other wedge surface and the strain producing means prevents movement of the strain producing means in the opposite direction,

means to selectively release the wedge members to permit movement of the strain producing means in one direction.

7. The transducer of claim **6** with said means to selectively release the wedge members comprising a piezoelectric actuator for each clamp assembly,

means to apply an electrical power source to said piezoelectric actuator to move said actuator in one direction for one direction of voltage polarity and in an opposite direction for the opposite direction of voltage polarity,

said piezoelectric actuator moving the wedge members of one wedge surface in one clamp assembly to a release position for one direction of voltage polarity and moving the wedge members of the other wedge surface in the said one clamp assembly to a release position for the other direction of voltage polarity.

8. A clamp assembly for selective one-way movement of a shaft comprising

a shaft,

a clamp assembly housing,

a pair of axially spaced annular wedge surfaces placed over said shaft,

a plurality of first wedge members being placed between one of said wedge surfaces and said shaft member, and a plurality of second wedge members being placed between the other wedge surface and said shaft member,

the wedge surfaces being inclined to the shaft axis so that movement of the shaft in one direction will cause the first wedge members of said one wedge surface to wedge between said one wedge surface and the shaft and movement of the shaft in the other direction will cause the second wedge members of said other wedge surface to wedge between the other wedge surface and the shaft,

piezoelectric means,

bidirectional electrical voltage means being applied to said piezoelectric means,

said piezoelectric means moving the first wedge members to a release position when electrical current is applied in one direction to the piezoelectric means and to move the second wedge members to a release position when the electrical voltage is supplied to said piezoelectric member in the opposite direction.

9. The clamp assembly of claim 8 with said piezoelectric means comprising

a piezoelectric disc secured at its outer circumference to the assembly housing and having an opening in the center thereof through which said shaft passes,

annular disengaging means being connected securely around the opening in the center of said disc,

said annular disengaging means being engageable with said first wedge members associated with said one wedge surface upon movement of said piezoelectric disc in one direction to move said first wedge members to a release position, and engageable with said second wedge members associated with said other wedge surface upon movement of said piezoelectric disc in the opposite direction to move said second wedge members to a release position,

said bidirectional electrical voltage source applying voltage potential to said piezoelectric disc in one direction to deflect said piezoelectric disc in said one direction and to apply voltage potential to said piezoelectric disc in the opposite direction to deflect said disc in said opposite direction.

10. The clamp assembly of claim 9 with each of said wedge members being spring urged to a wedging position.

References Cited by the Examiner

UNITED STATES PATENTS

3,211,931 10/1965 Tehon ---------- 310—8.3

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