United States Patent

[11] 3,596,116

[72] Inventor **Richard S. Walton**
Lancaster, Pa.

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[45] Patented **July 27, 1971**

[73] Assignee **Hamilton Watch Company**
Lancaster, Pa.

Original application Apr. 25, 1968, Ser. No. 724,144, now Patent No. 3,509,714. Divided and this application July 23, 1969, Ser. No. 855,793

[54] **PIEZOELECTRIC-FLUID ELECTROMECHANICAL TRANSDUCER**
1 Claim, 4 Drawing Figs.

[52] **U.S. Cl.** **310/8.6,** 310/8.1
[51] **Int. Cl.** **H01v 7/00**
[50] **Field of Search** ..... 310/8.1-—8.3, 8.5—8.7, 15, 17, 19, 30; 318/135; 60/54.5, 54.6

[56] **References Cited**

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Primary Examiner—Milton O. Hirshfield
Assistant Examiner—B. A. Reynolds
Attorney—Le Blanc & Shur

ABSTRACT: The transducer has a fluid chamber mounting a piezoelectric element at one end and a piston slidably mounted in a reduced diameter portion of the chamber opposite the element. A timebase, including a high frequency oscillator and a frequency divider, applies an electrical signal across the piezoelectric element whereby the element moves to displace the fluid in the chamber thereby driving the piston outwardly against the bias of a spring. The piston is coupled to the gear train of a timepiece. The timed electrical signal is thus converted to an incremental mechanical movement which is amplified by the fluid system to provide timed indexing of the gear train.

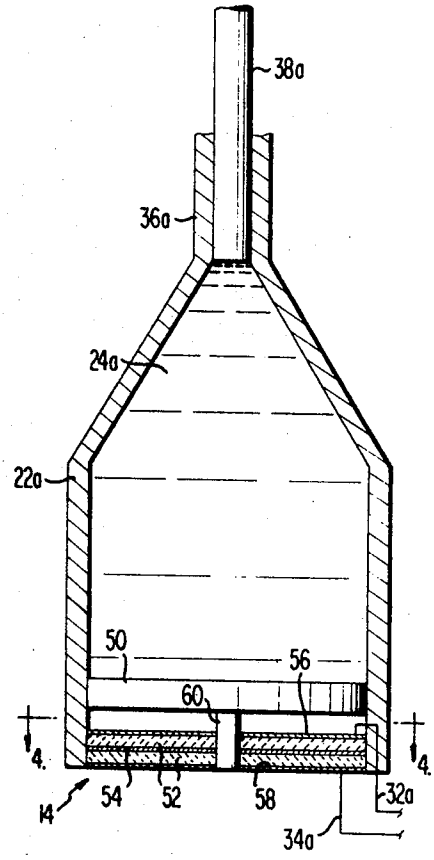


FIG. 1

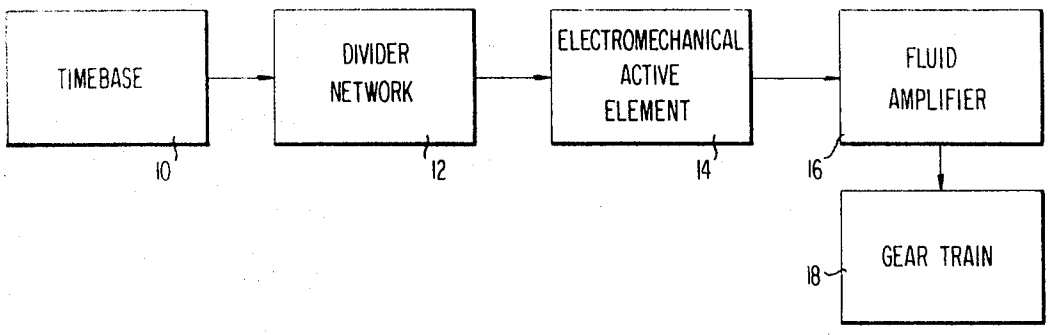


FIG. 2

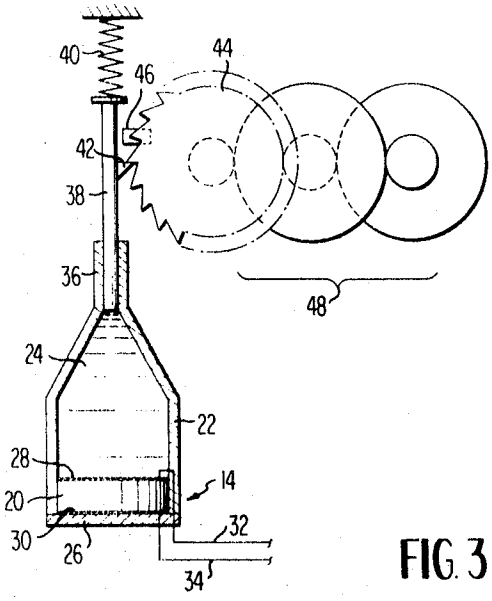
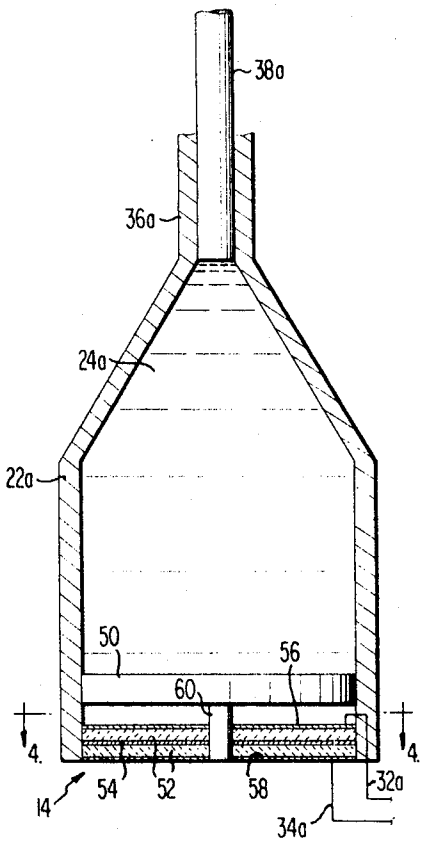


FIG. 3



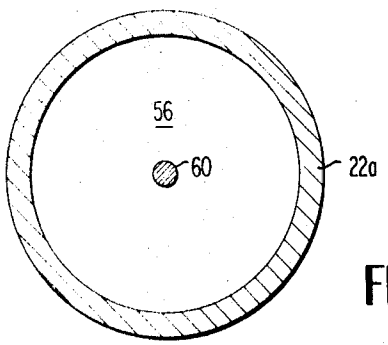


FIG. 4

INVENTOR
RICHARD S. WALTON

BY LeBlanc & Shur
ATTORNEYS

PIEZOELECTRIC-FLUID ELECTROMECHANICAL TRANSDUCER

This application is a division of copending application Ser. No. 724,144, filed Apr. 25, 1968, now U.S. Pat. No. 3,509,714.

The present invention relates to an electromechanical timepiece and particularly to a timepiece having an electrical-mechanical transducer including an electromechanically active element wherein the motion of the element under an applied electrical signal having a predetermined frequency is amplified through a fluid system to drive the gear train of a timepiece.

With the employment of periodic signal sources, such as crystal controlled oscillators or free-running multivibrators or the like, as high frequency timebases, it has been found desirable to provide direct electrical to mechanical energy conversions or transducers whereby the mechanical parts of the timepiece would be driven directly from the transducer. Complex electrical circuitry has heretofore been provided to perform this conversion. However, cost, power, and space limitations in timepieces, particularly watches, have effectively precluded use of such circuitry.

In direct electrical to mechanical conversions employing elements formed of electromechanically active material, including piezoelectric elements, the mechanical motion or distortion characteristic of the material when an electrical signal is applied across the elements is extremely small. Various attempts to amplify this mechanical motion have been tried. One such attempt employs stacked piezoelectric elements connected to a lever arrangement whereby the motion of the elements in response to an applied voltage across each element is amplified through the stack and lever arrangement. In this and other attempts, space and friction limitations have proven difficult to overcome and a usable magnitude of mechanical motion has been difficult to obtain.

The present timepiece employs an electromechanical transducer having an element formed of electromechanically active material which element moves or is distorted in a predetermined direction in response to an impressed electrical signal. The electrical signal is provided by a high frequency timebase, the output frequency of which is reduced through a frequency divider and impressed on the electromechanically active element. This element forms a wall portion of a fluid chamber which also has a reduced diameter area or restriction. A piston is slidably received in this reduced area and is biased inwardly into the fluid chamber by a spring. A tooth on the piston is disposed to engage the teeth on a ratchet wheel which is geared to the gear train of the timepiece. The element distorts or moves inwardly into the fluid filled chamber in response to an electrical signal impressed thereacross to drive the piston member outwardly against the bias of its spring, thereby driving the gear train. Due to the relative areas of the element and piston member which confront the fluid in the chamber, the incremental motion or distortion of the element is amplified to provide a piston displacement usable in and sufficient to drive the gear train of a timepiece.

Accordingly, it is a primary object of the present invention to provide an improved electrical-mechanical transducer having direct mechanical motion amplification.

It is another object of the present invention to provide an improved timepiece of the type employing an electrical-mechanical transducer.

It is still another object of the present invention to provide an improved timepiece having an electrical-mechanical transducer of the type employing electromechanically active material providing mechanical motion in response to an applied voltage.

It is a further object of the present invention to provide an improved timepiece which is simple in construction and has a minumum number of moving parts.

These and further objects and advantages of the present invention will become more apparent upon reference to the following specification, claims and appended drawings wherein:

FIG. 1 is a block diagram illustrating the power train of a timepiece constructed in accordance with the present invention;

FIG. 2 is a schematic illustration of an electrical-mechanical transducer and fluid amplifier employed in the timepiece hereof;

FIG. 3 is an enlarged schematic illustration of the fluid amplifier and another type of electrical-mechanical transducer;

FIG. 4 is a horizontal cross-sectional view thereof taken about on line 4–4 of FIG. 3.

Referring now to the drawings and particularly to FIG. 1, there is schematically illustrated a power train for the present timepiece comprising a high accuracy timebase **10**, the output frequency of which is divided by a divider network **12** to provide a frequency in a range useful to drive the gear train of a timepiece. Timebase **10** may comprise any suitable periodic signal source, for example, a crystal controlled oscillator, a free-running or a stable multivibrator, or any other type of periodic source suitable for timekeeping purposes.

Generally, the electrical signal from timebase **10** and divider network **12** is applied to a transducer **14** across an element thereof, formed of an electromechanically active material having the property of providing a physical distortion or movement when a potential gradient is applied across its major surfaces. Upon removal of the electrical signal, the element returns to its original shape. Elements having this type of mechanical action in response to an applied electrical signal are well known in the art and are most often piezoelectric elements, but may be magnetostrictive or electrostrictive elements as desired. As further seen in FIG. 1, the slight or incremental mechanical motion of the electromechanically active element **14** caused by the imposition of the electrical signal is amplified through a fluid system **16** to drive the gear train **18** of a timepiece.

Referring now to FIG. 2, there is shown an element **20**, preferably formed of electromechanically active material having the above-noted characteristics and disposed in and at the lower end of a generally cylindrical container or chamber **22** containing a fluid **24**. A base cap **26** is suitably secured to the sidewalls of container **22** in underlying relation to element **20**. One type of electromechanically active element **20** comprises a conventional piezoelectric element which may be formed of crystalline quartz, Rochelle Salt, ammonium dihydrogen phosphate, or the like, and which is provided electrically conductive coatings **28** and **30** on opposite surfaces thereof. The lower surface of element **20** is preferably fixed to cap **26** whereby element **20** is free for axial inward movement or distortion. Electrical wires **32** and **34** connect with conductive plates **28** and **30** on opposite sides of element **20** for applying the electrical signal from timebase **10** and frequency divider **12** across element **20**. Wire **32** extends upwardly within and is insulated from the sidewall of container **22** for connection with upper coating **28** while wire **34** may extend directly through cap **26** for connection with lower coating **30**. Alternatively, element **20** could be secured to the walls of container **22** about its periphery whereby element **20** would be free for axial movement in both directions.

The opposite end of chamber **22** has a reduced diameter portion **36** which slidably receives one end of a piston member **38**. A spring **40** connects to the opposite end of piston member **38** biasing member **38** inwardly into container **22** such that the lower end of member **38** is maintained in confronting relation with the fluid **24** in container **22**. A tooth **42** is formed on the side of piston member **38** for engagement with a ratchet wheel **44**, having teeth **45**. The teeth **45** on ratchet wheel **44** are preferably formed of ferromagnetic material and a magnet **46** is positioned in opposed relation to one of the teeth **45** to provide a restraining force to wheel **44**. The gear train of a timepiece is schematically illustrated at **48** and is suitably geared to wheel **44**. It will be seen that axial reciprocation of piston member **38** steps ratchet wheel **44** unidirectionally to drive gear train **48**. Magnet **46** acts on the ratchet wheel teeth **45** as they are successively positioned in opposed relation thereto to restrain index wheel **44** from

reverse rotation when tooth **42** clicks back to the normal illustrated position. This type of magnet-tooth cooperation is described in U.S. Pat. No. 3,158,988 of common assignee herewith.

In use, the electrical signal from the timebase **10** and frequency divider **12** is periodically applied across electromechanically active element **20** via wires **32** and **34** and conductive surfaces **28** and **30**. With each electrical pulse, element **20** characteristically moves or distorts in an axial direction and, with cap **26** preventing axial movement of element **20** in a downward direction as seen in FIG. **2**, element **20** moves axially into container **22** exerting a force through fluid **24** against member **38**. Piston member **38** is thus displaced outwardly against the bias of spring **40** and a tooth **42** steps ratchet wheel **44** (such that the next tooth **45** is positioned in opposed relation to magnet **46**), thereby driving gear train **48**. Upon removing the applied electrical signal, element **20** returns to its normal configuration whereby spring **40** urges piston member **38** inwardly into container **22** to locate tooth **42** behind the next tooth **45** on ratchet wheel **44** with magnet **46** restraining index wheel **44** from reverse rotation as tooth **42** clicks past the next tooth. This operation is repeated and it will be seen that the reciprocating motion of piston member **38** follows the periodic movement of element **20** and the frequency of the applied signal to drive ratchet wheel **44** and gear train **48** unidirectionally.

Referring now to FIGS. **3** and **4**, there is shown a cylindrical chamber **22***a*, similar to the chamber **22** in the previous embodiment, the lower end of a piston member **38***a* being slidably received in a reduced diameter portion **36***a* of a container **22***a* containing fluid **24***a*. A piston or disc **50** is slidably received through the lower open end of container **22***a*. In this form, the electromechanical active element **14** is of the "-Bimorph" type and comprises a pair of layers **52** of piezoelectric ceramic material separated by a metallic spacer **54** which may be formed of brass. Conductive electrode layers **56** and **58** are attached in any suitable manner to the outer surfaces of the piezoelectric layers **52**. This electromechanically active "-Bimorph" element has an annular configuration with a central aperture. A pin **60**, secured to the disc **50**, is suitably fastened to the "Bimorph" element within its aperture. The annular "-Bimorph" element is rigidly secured about its periphery to the lower end of container **22***a* and a pair of electrical wires **32***a* and **34***a* connect with electrode layers **56** and **58** respectively for applying the periodic electrical signal from timebase **10** and frequency divider **12**.

In use, the periodic application of the electrical signal from timebase **10** across the "Bimorph" element characteristically moves or distorts the annular element in an axial direction toward and away from fluid chamber **22***a*. This mechanical distortion or movement reciprocates piston **50** within chamber **22***a* exerting a force through the fluid **24***a* against member **38***a*. The action of piston member **38***a* is similar in this form to the action of piston member **38** in the previous form and accordingly the periodic movement of the "-Bimorph" element is followed by reciprocating motion of piston member **38***a* to drive ratchet wheel **44** and gear train **48** unidirectionally. It will be appreciated that "Bimorph" element **14** could act directly against the fluid **24***a* without the intermediary of piston **50** if desired.

It is a feature of the present invention that the slight or incremental mechanical movement of the electromechanical active element **14** in each form hereof in response to the imposition of an electrical signal is amplified through the fluid system to displace the associated piston member **38**, **38***a* a distance sufficient to provide useful work, i.e., sufficient to step the gear train of a timepiece. To this end, the area of piston member **38**, **38***a* which confronts fluid **24**, **24***a* in container **22**, **22***a* is preferably considerably smaller than the respective areas of element **20** and piston **50** which confront the fluid. The displacement of piston member **38**, **38***a*, being proportional to the ratio of the areas of the element **20** and piston member **38**, or piston **50** and member **38***a*, as the case may be, which confront the fluid, is thus amplified to the extent that the displacement is sufficient to step wheel **44** and hence drive gear train **48**.

It is thus seen that the objects of the invention are fully accomplished in that there is provided a simple and improved electrical-mechanical transducer for a timepiece of the type utilizing an electromechanically active material. Moreover, the slight or incremental mechanical movement of the electromechanically active element is uniquely amplified through the fluid system hereof to provide a mechanical movement or displacement sufficient to step an index wheel and thereby drive the gear train of a timepiece.

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiment is therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced therein.

What I claim and desire to be secured by U.S. Letters Patent is:

1. An electromechanical transducer comprising a fluid container, a relatively smaller piston closing off one portion of said container, a relatively larger piston closing off a second portion of said container and adapted to communicate in force transfer relation with said smaller piston through the fluid in said container, an annular piezoelectric bimorph spaced from said larger piston and having its outer edge fixed to a support, means for coupling an electrical signal to said bimorph, and means connecting said larger piston to the center of said bimorph.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,596,116 Dated July 27, 1971

Inventor(s) RICHARD S. WALTON

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In Column 1, line 72, "minumum" should read --minimum--.

In Column 2, line 36, "preferably formed" should read --preferably cylindrical, formed--.

Signed and sealed this 22nd day of February 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents