Unidirectional Single Piston Ultrasonic Transducer

Prior Art (known patents and designs):

All double piston, single-element or multi-elements sandwich acoustic transducers, piezoelectric and magnetostrictive stacks, and all types of traditional Bolted Langevin Transducers, as well as Ultrasonic Cleaning and Ultrasonic Welding transducers belong to the Prior Art in the field of acoustic transducers. Double piston oscillating mode (axial both side contraction-extension mode) is an essential characteristic of all **Prior Art** transducers.

European patents:
Applicant: Gould Inc. Inventor: Thompson, Stephen
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(This patent presently belongs only to a public domain. Officially it is abandoned by its owner/s.)

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Abstract of Invention:

Unidirectional Single Piston Ultrasonic Transducer

Unidirectional sandwich transducer which includes a center mass freely placed between two active transducer element stacks and two end masses where all of them are coupled only by rigid stress rod between two end masses and where one of two active transducer element stacks can be replaced by solid and acoustically passive isolator stack. The center mass is performing free and not attenuated single piston oscillations between two active transducer element stacks and two end masses realized by mutually opposite phase polarity of active transducer elements while driven by the same input electrical signal. The center mass is also performing free and not attenuated single piston oscillations between one active transducer element stack and one solid and acoustically passive isolator stack and two end masses. The transducer is using electrical and emitting acoustic energy only when placed in contact with some external mass and shape and size of externally contacted mass have no influence to transducer's center mass vibrations. When center mass is performing single piston movement and when transducer is not mechanically loaded the total transducer length is constant and two end masses are not oscillating. The transducer is ideal for agitating arbitrary distant and arbitrary shaped liquid and solid masses placed in different vessels or pipes transferring its vibrations via waveguide solid rod connected between the transducer and a loading mass. The single piston transducer connected perpendicularly to a solid tube can agitate different radial and circumferential tube vibration modes without the need of exciting longitudinal and axial tube modes. The transducer can also be used as a vibration receiver or sensor.

BACKGROUND OF THE INVENTION:

All today's ultrasonic transducers (Prior Art) are operating in a kind of simple or mixed, contraction-extension vibration mode. This usual mode of oscillations can be described when one or more, axial, lateral or any other space dimension of transducer is/are periodically changing length (following some sinusoidal function). Briefly, we can say/simplify that all usual ultrasonic transducers (performing contraction-extension) have as an input some oscillating electrical signal, and producing as an output one (proportional) oscillating (mechanical) amplitude. In other words, certain length of usual/traditional ultrasonic transducers is time dependant, performing contraction-extension, following the function: $L(t) = L_0 + a \sin(2\pi ft)$, $L_0 = Const$, $a = const$. This effect is realized using electrostrictive or magnetostrictive properties of certain active materials, which are parts of ultrasonic transducers (or sources of vibrations). Active sources of vibrations are placed somewhere inside (say in the middle) of transducer body, making one sandwich structure bounded by two end-metal-masses. This way, oscillations of central and active vibration source (electrostrictive or magnetostrictive materials) is directly coupled to surrounding end-metal-masses, and metal masses are performing contraction-extension, following oscillations of active transducer sources (piezoceramics, for instance), meaning that all elements of the sandwich structure of one ultrasonic transducer are oscillating in a certain contraction-extension mode (changing their lengths).

Here proposed new types of ultrasonic transducers (the current invention) are not changing their principal (axial) length, which is always constant (in no-load conditions). Briefly, we can say/simplify that new types of ultrasonic transducers have as input some oscillating electrical signal, and producing as an output a proportional, oscillating (mechanical) force, or pressure, or quantity of motion. This is possible regarding to the modification of sandwich structure of ultrasonic transducers. Traditional ultrasonic-transducers' sandwich structure (Prior Art) has three parts: one central and active vibration source (piezoceramics stacks) and two end-metal-masses. New and modified sandwich structure (present invention) has two active vibration sources (working in opposition: one is extending, the other is contracting and vice-versa), bounded by three metal masses. This way, only the center mass is performing kind of translating, single piston vibrations, changing only its position (but not dimensions) and two end metal masses are always in stable position (without any change of their dimensions). This is possible because two active vibration stacks that are placed in between three metal masses are mutually compensating each other vibrations, meaning that one of them is in the phase of extension and the other is contracting for the same amplitude. In a conclusion: Three masses sandwich transducer, or single piston oscillating transducer (the current invention) is oscillating structure in which only center mass is performing single piston type vibrations, and end masses are not moving. Of course, there is a kind of pressure-ultrasonic-wave that is permanently travelling from one end mass to other, and vice-versa, like light beam reflecting endlessly between two stable mirrors.

There are many design options of here described three mass transducers, depending how we are intending to use them. Basically, because of the mechanical law of momentum conservation, three masses sandwich transducer (or single piston transducer), when in a contact with some other (external) mass

(or liquid) is producing unidirectional (single piston type) acoustical wave, which is, later on, producing real mechanical vibrations in external media (having all parameters of oscillatory motion such as: amplitude, velocity and pressure, realized inside of external media).

Traditional, double piston oscillating transducers described in many patents (**Prior Art**) can be represented by some of the mass-spring oscillating structures similar to ones given in Fig. 1(a) and Fig. 2(a). End masses 3 and active (piezoelectric or magnetostrictive) vibrating elements 1 are strongly fixed by stress rod or central bolt 6, applying necessary pressure on active vibrating elements 1. If we neglect all resistive damping, attenuation and friction elements of such mass-spring structures, the most representative simplified, equivalent mechanical circuits, corresponding to Fig. 1(a) and Fig. 2(a), are given on Fig. 1(b) and Fig. 2(b). For traditional double piston, sandwich transducer structures **(Prior Art**) is typical that both of oscillating masses 3, m_1 and m_2, are connected with a common central bolt 6, which also presents active spring element that has stiffness coefficient S_b (see Fig. 1(b)). In reality, transducer's effective stiffness coefficient $S_{b,c}$ is the stiffness combined of the central bolt 6 stiffness S_b with all other elastic parameters S_c of active vibrating elements 1, belonging to the structures presented on Fig.1(a),(b) and Fig. 2(a),(b). Because of that reason, on the Fig. 1(b),(c),(d), Fig. 2(b) and Fig. 3(b),(c),(d) we use symbol **Sb,c** for effective stiffness signifying that corresponding spring element is a combination of stiffness parameters of the stress rod or central bolt 6, and active vibrating stack elements 1 (or parallel combination between S_b and S_c).

In operation, all traditional transducer structures (**Prior Art**: see Fig. 1(a) and Fig. 2(a)) are oscillating in the contraction-extension, or double (mutually opposite) piston mode, presented on Fig. 1(c) and Fig. 1(d), meaning that both end masses 3 are oscillating in mutually opposite phase. Fig. 2(a) presents simple combination of two traditional transducers given on Fig.1 (described in the European patent: Gould Inc. Inventor: Thompson, Stephen, Publication number: 0 209 238, A2, int. Cl.: H 04 R 17/10, from 21.01.87. This patent is already in a public domain since its owner decided not to extend it). Transducer on Fig. 2(a) gives some more flexibility and oscillating freedom to introduce different driving signals into upper and lower part of one transducer, but basically this is simple mechanical combination of two traditional (Prior Art) transducers presented on Fig. 1(a).

Vibrating energy 5 of a traditionally known transducer/s (Fig. 1(a) and Fig. 2(a)) is radiated into external medium when (at least) one of oscillating masses 3 is in mechanical contact with external medium (acoustically coupled with external medium). The biggest disadvantage of double piston transducers (Fig. 1(a) and Fig. 2(a)) is in the fact that in the process of mechanical loading, acoustic parameters of external medium, and mechanical coupling with a transducer, are creating significant damping and attenuation, significantly changing the parameters of equivalent oscillatory structures given on Fig. 1(b), (c), (d) and Fig. 2(b). Electroacoustic or electromechanical efficiency of double piston transducers (in any combination similar to Fig. 1(a) and Fig. 2(a)) is very much dependent on shape, size and acoustical and mechanical parameters of externally connected medium. Different and complicated design techniques for resonant and impedance matching are necessary to be applied in order to achieve optimal energy transfer from double piston transducers towards external medium (also subject of **Prior Art**).

The majority of loading, impedance and frequency matching and mechanical coupling disadvantages of double piston transducers can be avoided if oscillating mass of the transducer is not in a direct contact with external medium (Fig. 3(a)). One of such transducer design (**the current invention**) is presented on Fig. 3(a). Equivalent mechanical, oscillating circuit of this design is presented on Fig. 3(b). The stress rod or central bolt 6 (in Fig. 3(a)) is only and directly connecting two end metal masses 3. The center mass 4, m_c, is freely placed between two active vibrating layers 1 (piezoceramics), and all of them are in the sandwich between two end metal masses 3, m_1 and m_2, mechanically connected by the stress rod or central bolt 6 (which is touching only end masses). Neither center mass 4 (=) m_c, nor active vibrating elements 1 are in contact with stress rod or central bolt 6. Active, vibrating (piezoceramic) layers 1 are electrically polarized opposite to each other (placed in opposite polarity position during assembling) producing single piston oscillations of center mass 4. When upper active layer is in the phase of axial contraction, coincidentally and synchronously, the lower active layer is in the phase of axial extension, and vice versa, this way producing single piston oscillations of central mass 4, mc, presented on Fig. 3(c) and Fig. 3(d). Both active vibrating layers 1 (piezoceramics or magnetostrictive material) are electrically connected in parallel and driven by the same signal coming from the single signal source (for instance ultrasonic generator, oscillator, amplifier; -see Fig. 4). It is also enough to have only one active transducer element stack, instead of two active transducer element stacks, and replace the other active stack by a solid, passive electrically isolating stack (ceramic), which has good elastomechanical properties (and single piston oscillations will also be produced on the same way above described, since acoustically passive stack will react only as a mechanical spring and electrical isolator). The total length between two end masses 3 of the transducer on Fig. 3(a) is not changing (in no-load conditions, in air) since one of active vibrating layers 1 is contracting and the other extending for the same displacement, opposite to double piston transducers presented on Fig. 1(a) and Fig. 2(a). In the case of double piston transducers (driven by single electrical source) it is usually possible to find stable point or plane that presents center of mass (center of inertia, and/or center of gravity) somewhere inside of the transducer structure (usually named vibration nodal plane). In the **double piston** transducer's center-of-mass velocity (of transducer's nodal plane) is equal zero in every time instant (since mutually opposite contraction and extension of end masses 3 is canceling the resulting momentum or force in a nodal plane). Opposite to **double piston** transducers, exact and stable position of **single-piston**-transducer's nodal plane in every time instant cannot be found, since center mass 4 is always in a single piston movement. Single piston transducers can have the nodal plane only found as an average position regarding certain time interval (during transducer operation), but it cannot be found in every time instant. We can say that double piston transducers (**Prior Art**) are fully balanced in a nodal plane regarding resulting mechanical momentum (equal zero), and single piston transducers (**this Invention**) are unbalanced (regarding resulting mechanical momentum in their center of inertia). Unbalanced mechanical momentum transducer (Fig. 3(a)) has piston-oscillating center of mass and this is the source of outgoing radiation 5 of a single piston transducer, when in contact with some external medium (**the current invention**).

Similar to the situation as two traditional transducers, Fig. 1(a), are connected in one transducer, Fig. 2(a), we can also connect (in axial line) two or more single piston transducers, Fig. 3(a), producing one extended and multiple single-piston structure. This way, using different signal input combinations and combining phase polarity of active transducer elements, we can produce different vibration outputs, fully unidirectional output, frequency, amplitude and phase modulated output etc., Fig. 10(a),(b). This way we also increase the total acoustic power of multiple, single piston transducer.

Especially, when connected perpendicularly to a solid tube (via acoustic waveguide rod 9, Fig. 9), **single piston transducer** (present invention) can agitate different radial, circumferential, cylindrical and transversal tube vibration modes, without the direct need of agitating longitudinal (and axial) tube modes (what is very beneficial for various liquid processing or liquid atomization, while keeping high flow rate).

Important characteristics of single piston transducers (the current invention) are:

1. **This transducer (the current invention) is the source of ultrasonic force or pressure, but it is also a source of momentum P = mv (quantity of motion), because regarding to the mechanical law of Momentum conservation, such new kind of transducers are possible to be designed ($P_{inp.} = P_{outp.}$, F = dP/dt , $F_{inp.} = F_{outp.}$, Pressure = F/Surface). As we know, by definition, the force is equal to the first time derivation of momentum.**
2. **In order to give much better description of new transducers (the current invention) it is useful to mention well-known electro-mechanical analogies (there are several systems of mutually equivalent electro-mechanical analogies, but we shall take only the most convenient of all of them). For instance, let us use the following system of analogies: Electrical Current ⇔ Mechanical Force, and Electrical Voltage ⇔ Mechanical Velocity. In Electronics, because of convenience and different application reasons, we are designing/producing electrical power sources/supplies, which are stabilized-constant output voltage, or stabilized-constant output current sources. In the theory of electrical circuits (for theoretical and practical reasons) we use idealization/approximation of saying that one electrical source can be ideal current generator, or ideal voltage generator (relating those definitions/approximations to internal impedance of such sources, and to their electrical outputs). Now, we can say that traditional two-mass (contraction-extension) ultrasonic transducers are velocity generators, or much closer/analog to real voltage generators, and three-mass, new ultrasonic transducers are force generators, or analogue/close to real current generators. In reality, for the purpose of ultrasonic welding applications, traditional ultrasonic transducers are driven/controlled to produce constant output (mechanical) amplitude or velocity, but it was not realized that full analogy can be established (on the previously explained way) between electrical and mechanical sources. Of course, when we say constant velocity or constant force ultrasonic vibrations, this usually means constant RMS or constant peak-to-peak, or constant average output.**
3. **New types of transducers (the current invention) have stable resonant frequency, as traditional transducers (Prior Art), but this frequency can be modulated/changed in a much wider frequency interval than in the case of traditional two-mass transducers. General characteristic of new transducers is that they are able to produce single piston-type, unidirectional and progressive ultrasonic waves that are not (so much) dependent of mechanical load as traditional transducers are.**

Important advantages of single piston transducers (the current invention) are:

1. **Traditional two-mass, double piston, sandwich transducers (Prior Art) are very much dependant of attached mechanical load, because one of oscillating masses must be in a contact with external working media. This way oscillating structure is non-symmetrically loaded and mechanical quality factor of transducer is decreasing, leading to high attenuation of transducer oscillations, and to high mechanical losses in such transducers. Single piston transducer is always symmetrically loaded on both end masses (because end masses are mutually in a rigid contact by central bolt, and they are not moving), and third piston-vibrating central mass is always in a free vibrations (newer in the contact with external media). Active vibration layers are performing/simulating a kind of mechanical spring, combined with central bolt that is connecting two end masses. Three masses sandwich transducer, or single piston transducer (present invention) can be rigidly fixed or mechanically loaded to external media without disturbing oscillations of its central mass.**
2. **Single piston transducer (present invention) can be combined/coupled with traditional, two masses, double piston sandwich transducers (prior Art) in order to produce acoustically modulated progressive waves, for different technological applications.**
3. **Single piston transducer (present invention) can be applied as a pressure or force source, enabling high-energy (unidirectional) acoustical wave penetration through very thick metal masses (what is not possible using traditional transducer).**

4. **High energy, Acoustical wave-guide lines, analogue to fiber optic wave-guides, can be easily realized using single piston sandwich transducers (what is not possible using traditional transducer).**
5. **New transducer (present invention) is almost single, axial/longitudinal vibration source (and radial oscillating mode is either very small, or does not exist).**
6. **The same transducer type can easily be used as a sensor of vibrations, separating only one (axial) vibration beam. External mass can not affect characteristics of such sensor.**

SUMMARY OF THE INVENTION:

It is an object of the present invention to provide single piston oscillating transducer where oscillating mass is not in a direct contact with external medium and where equivalent mechanical oscillating circuit of the transducer is not directly attenuated by external medium.

It is another object of the present invention to produce device capable of efficient driving of external medium masses of arbitrary shapes and sizes without necessity of resonant tuning and impedance matching between the transducer and external mass all of that is impossible using double piston transducers.

It is another object of the present invention to produce device capable to be separated with long solid rod from external medium mass and to introduce strong vibrations into heavy duty operating conditions without necessity of resonant tuning and impedance matching between the transducer and external mass.

It is another object of the present invention to produce device capable to penetrate arbitrary thick solid masses and to introduce strong vibrations into heavy duty operating conditions without necessity of resonant tuning and impedance matching between the transducer and external mass.

It is another object of the present invention to produce device capable to be mechanically coupled with traditional double piston transducers in order to produce progressive acoustically modulated waves.

It is still another object of the present invention to produce longitudinally oscillating single piston device capable of single direction driving of external medium in the direction of its piston oscillations.

It is another object of the present invention to produce device capable of receiving external medium vibrations coming from a single direction collinear with longitudinal transducer’s axis.

It is still a further object of this invention to achieve the preceding objects in a relatively compact, lightweight and inexpensive device.

The present invention achieves the above objects by freely placing of center mass between two piezoelectric stacks of a double piston transducer and mutually inverting electrical polarity of piezoelectric stacks in order to achieve single piston movement of a center mass. Two piezoelectric stacks are electrically connected in parallel and driven by the same electrical source. One of piezoelectric stacks can be replaced with an inactive ceramic stack and single piston movement of a center mass will again be maintained. By proper selection of the acoustic impedances and dimensions of metal masses, it is possible to achieve a broad range of acoustic performance characteristics.

These, together with other objects and advantages, which will be subsequently apparent, reside in the details of construction and operation as more fully hereinafter described and claimed, reference being had to the accompanying drawings forming a part hereof, wherein like numerals refer to like parts throughout.

BRIEF DESCRIPTION OF THE DRAWINGS:

In all drawings, from Fig. 1(a), (b), (c), (d) up to the Fig. 10 (a), (b), we use the same symbols for the corresponding elements, which have the same technical meaning, position and function, as follows:

1, 1', 1'', 1''' and 1'''' are the elements of active (piezoelectric) stacks.
2, 2' and 2'' are active (piezoelectric or magnetostrictive) stacks.
3, 3', 3'' and 3''' are transducer end masses m_1, $m_{1,2}$ and m_2.
4, 4' and 4'' are the center masses (m_c, m_c' and m_c'') of the transducer.
5 present the radiation of acoustic energy into external medium.
6 is the stress rod or central bolt.
S_b is a stiffness coefficient of stress rod or central bolt 6.
S_c is a stiffness coefficient of active stacks 2, 2' and/or 2''.
$S_{b,c}$ is an effective, combined stiffness coefficient of stress rod 6 and active stack 2, 2' and/or 2''.
7 represent external acoustic medium.
8 is a signal generator.
9 is a waveguide rod.

Fig. 1(a) depicts, in longitudinal cross section, the elements and construction of a prior art double ended, double piston longitudinal transducer;

Fig. 1(b) is the equivalent circuit for the transducer of Fig. 1(a);

Fig. 1(c) is the equivalent circuit for the transducer of Fig. 1(a) in the phase of transducer contraction;

Fig. 1(d) is the equivalent circuit for the transducer of Fig. 1(a) in the phase of transducer extension;

Fig. 2(a) depicts, in longitudinal cross section, the elements and construction of a prior art double ended, double piston longitudinal transducer combined from two prior art transducers, similar as shown on Fig. 1(a);

Fig. 2(b) is the equivalent circuit for the transducer of Fig. 2(a);

Fig. 3(a) depicts, in longitudinal cross section, the elements and construction of the single piston longitudinal transducer according to the present invention;

Fig. 3(b) is the equivalent circuit for the transducer of Fig. 3(a);

Fig. 3(c) is the equivalent circuit for the transducer of Fig. 3(a) when center mass 4 is in its upper position;

Fig. 3(d) is the equivalent circuit for the transducer of Fig. 3(a) when center mass 4 is in its lower position;

Fig. 4 depicts electrical connection of active stacks, and electrical signal input into transducer presented on Fig. 3(a), according to the present invention;

Fig. 5 presents a way of direct mechanical fixation of the single piston transducer (the present invention) to a solid load, or external medium 7;

Fig. 6 presents the way of direct mechanical fixation of the single piston transducer (the present invention) to a solid load, realized directly on the center mass 4;

Fig. 7 presents the way of direct mechanical fixation of the single piston transducer (the present invention) to a thick solid plate, when external medium 7 is on the opposite plate side, and when the front emitting mass 3' is replaced by thick and solid plate;

Fig. 8 presents the way of direct mechanical fixation of the single piston transducer (the present invention) to a sonotrode or amplitude-amplifying tool;

Fig. 9 presents the use of long mechanical waveguide rod 9, as the interface between transducer (the present invention) and external medium.

Fig. 10(a) and 10(b) depicts, in longitudinal cross section, two variants of extended single piston transducer structures (present invention) combined by connecting two single piston transducers (also present invention), similar as shown on Fig. 3(a).

DESCRIPTION OF THE PREFERED EMBODIMENTS:

The present invention (Figs.: 3, 4, 5, 6, 7, 8, 9, 10; -(a), (b), (c), (d)) achieves unidirectional response in a double piston transducer element by including an additional mass in the center of the piezoelectric stack, and by mutually inverted electrical polarity of the two ceramic stacks thus created, consequently producing single piston movement of the center mass. Fig. 3(a) illustrates a double-ended transducer with an extra mass 4, which will hereafter be called the center mass, mc. The center mass 4 is positioned between active transducer stacks 2' and 2" and head masses 3' and 3". A single stress rod 6 compressively biases the active piezoceramic stacks 2' and 2". 1' and 1'' are the elements of active transducer stack (piezoceramics). The center mass 4 allows vibration to be exchanged between the stacks 2' and 2" and between the masses 3' and 3", by performing single piston movement in the same time. The two head masses 3' and 3" (Fig. 3(a)) may be of identical construction as in the case for the head masses 3 of the prior art device (see Fig. 1(a) and Fig. 2(a)), or they may be different to provide differing radiation properties to the two sides of the device. The two active elements 2' and 2" may be identical materials or they may be different to tailor the response in the two directions. The transducer of Fig. 3(a) is assembled in a manner substantially identical to the assembly of one of the prior art transducers of Fig. 1(a) and Fig. 2(a), except the very important fact that stress rod 6 is not fixed to the center mass 4 and that active piezoceramic stacks 2' and 2'' are assembled mutually in opposite electrical polarization, all electrically connected in parallel (see Fig. 4), thus enabling single piston movement of the center mass 4. The active transducer elements 1' and 1'' can be piezoelectric elements manufactured from a piezoelectric ceramic material, such as a lead zirconate titanate formulation, or magnetostrictive elements in an functionally equivalent configuration, or at least one stack element should be made from active transducer material, and the other can be replaced with inactive ceramic material. The adjustment of the comprehensive bias using the stress rods 6 is within the ordinary skill in the art. Other features of typical transducers such as insulating washers, wiring, electrical contacts etc. are well known to those of ordinary skill in the art and can be found for example, U.S. Patent No. 3,309,654 to Miller.

However, it is possible to have a single stress rod 6 connecting all three masses (end masses 3' and 3'' and center mass 4) under the condition that total transducer design will enable only single piston movement of center mass 4, keeping two end masses 3' and 3'' in a stable position (not changing the total length of the transducer, as presented on Fig. 3 (c) and (d)). In all situations, here described single piston transducer, Fig. 3(a) (**present invention**), is driven by singe electrical source 8 (ultrasonic generator, power oscillator, amplifier; -see fig. 4), opposite to the situation (see Fig. 2(a)) described in the European patent: "Gould Inc. Inventor: Thompson, Stephen, Publication number: 0 209 238, A2, int. Cl.: H 04 R 17/10, from 21.01.87", where two electrical signals (or ultrasonic generators) are separately driving the active transducer elements 2' and 2''.

The simplified mechanical equivalent circuit representation for the transducer of Fig. 3(a) is shown in Fig. 3(b). This circuit includes two active piezoelectric stacks 2' and 2'' (or one piezoelectric stack and the other inactive ceramic stack), each of which is represented by its stiffness coefficient S_c (or S_c' and S_c'', respectively), and the stress rod

6 represented by its stiffness coefficient S_b. Comparing equivalent mechanical circuits of double piston transducers (**Prior Art**) presented on Fig. 1(b) and Fig. 2(b) with the circuit on Fig. 3(b), we can conclude that **present invention**, Fig. 3(b), has an internally closed-loop mechanical circuit configuration (closed by stress rod or central bolt 6), and traditional transducers have linear, open-loop (or open-ended) mechanical configuration. Any mechanical or electrical loading unbalance or disturbance of the single piston transducer (in operation), presented on Fig. 3(a), will be auto-corrected and bypassed internally, trough the closed-loop mechanical circuit presented on Fig. 3(b), what is not the case with double piston transducers (**Prior Art**). The necessary supporting information regarding different mass-spring oscillating systems can be found in the literature: FORMULAS FOR NATURAL FREQUENCY AND MODE SHAPE, Robert D. Blevins Ph.D., Robert E: Krieger Publishing Company, Krieger Drive, Malabar, Fl 32950, ISBN 0-89874-791-0).

Fig.4 shows a representative configuration for the transducer (current invention) and single driving electronics to provide the performance possibilities discussed above. This figure shows an electrical signal generator 8 which provides the system input. Since the center mass 4, 4’, 4’’ (Figs. 3, 4, 5, 6, 7, 8, 9, 10) has certain inertia, it is clear that input electrical signal into transducer and produced acoustic waves inside of transducer structure will have different oscillatory speeds in comparison with the oscillatory speed of center mass 4. Because of that, by introducing the electrical signal, which has convenient amplitude, frequency and phase modulation (even applying PWM signals = Pulse Width Modulated), we can achieve many of extraordinary and unique acoustic effects such as unidirectional wave emission, large frequency-band sweeping etc., what is impossible to realize with traditional transducers (Prior Art transducers).

Fig. 5 and Fig. 6 are examples of the mechanical fixation to external medium 7, and use of the new device as an emitting transducer or receiving sensor.

Fig. 7 and Fig. 8 are two more examples of mechanical fixation of the transducer directly to external medium 7, eliminating the front emitting mass 3’ (Fig. 7), or transforming front emitting mass 3’ into amplifying sonotrode (Fig. 8). Fig. 7 also presents mechanical coupling arrangement when emitting energy of transducer should penetrate thick metal mass and irradiate active external medium 7.

The extended single piston transducer structure, Fig. 10(a),(b), presents two examples of the transducers made by connection of two single piston transducers presented on Fig. 3(a), on the same way as Fig. 2(a) presents extended structure made by connection between two transducers presented on Fig. 1(a), in order to produce high power and multiple driving options transducers. Similar extended structure/s can be produced connecting (in line) several of single piston transducers.

An additional alternative embodiment of the present invention can achieve further performance enhancement in some applications by providing somewhat different dimensions and/or materials for the left and right transducer elements. Modifications of this type could allow the rightward and leftward radiation to be optimized for somewhat different operating frequency bands, and thus increase the total operating bandwidth of the transmitting system.

The many features and advantages of the present invention are apparent from the detailed specification and thus it is intended by the appended claims to cover all such features and advantages of the device which fall within the true spirit and scope of the invention. Further, since numerous modifications and changes will readily occur to those skilled in the art, it is not desired to limit the invention to the exact description and operation illustrated and described, and accordingly, all suitable modifications and equivalents may be resorted to falling within the scope of the invention.

CLAIMS:

1. A single isolated-piston vibrating middle mass transducer, comprising:
first and second head masses in contact with an acoustic medium;
first and second active transducer elements oppositely polarized and respectively bordering said first and second head masses; and
middle mass, bordering said first and second active transducer elements, for transferring vibration between said first and second transducer elements, and allowing vibration by said middle mass to be alternatively enhanced by the vibration of the both of said active transducer elements oppositely polarized and always operating in a mutually opposite phase, and producing single piston movement of the middle mass.

2. A transducer as recited in claim 1, wherein said middle mass is a center mass.

3. A transducer as recited in claim 1, wherein said first and second head messes are of unequal mass.

4. A transducer as recited in claim 1, wherein said first and second active transducer elements oppositely polarized comprise different active transducer materials, or one active and one passive transducer material.

5. A transducer as recited in claim 1, further comprising single drive means, electrically connected in parallel to said first and second active transducer elements, for electrically driving said first and second active transducer elements with the same signal in a mutually opposite phase.

6. A transducer comprising:
a first head mass in contact with an acoustic medium;
a first active transducer element bordering said first head mass;
a center mass bordering said first active transducer element;
a second active transducer element bordering said center mass; and
a second head mass bordering said second active transducer element and in contact with acoustic medium.

7. A transducer as recited in claim 6, further comprising single drive means, electrically, connected in parallel to said first and second active transducer elements oppositely polarized, for driving said first and second active transducer elements with the same signal in a mutually opposite phase where one of active transducer elements can be replaced by a passive ceramic element.

8. A transducer as recited in claim 6, further comprising single receive means, electrically connected to said first and second active transducer elements oppositely polarized, for receiving electrical signal produced by said first and second active transducer elements connected in parallel where one of active transducer elements can be replaced by a passive ceramic element.

9. A transducer as recited in claim 6, further comprising:
a fixed stress rod connected between said first and second head mass;

10. A transducer as recited in claim 6, wherein said center mass has a hole therethrough and said transducer further comprises a stress rod connected between said first and second head masses trough the hole in said center mass.

11. A transducer as recited in claim 6, wherein said center mass has a threaded hole therethrough and said transducer further comprises a single and threaded stress rod connected between said first and second head masses trough the threaded hole in said center mass.

12. A transducer/s as recited in claims 1, 6, 9, 10 and 11, further comprising two or more single isolated-piston transducers, rigidly connected face-to-face, along their longitudinal axis.

13. A transducer/s as recited in claim/s 1, 6, 9, 10, 11 and 12, further comprising rigidly coupled waveguide rod to the first or second head mass in contact with an acoustic medium.

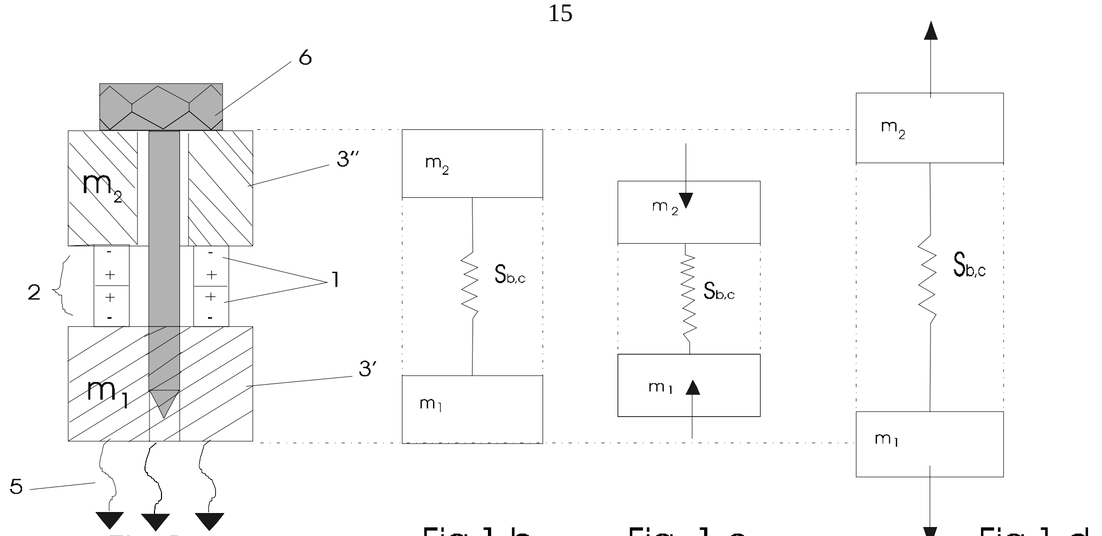

Fig.1.a Fig.1.b Fig. 1.c Fig.1.d

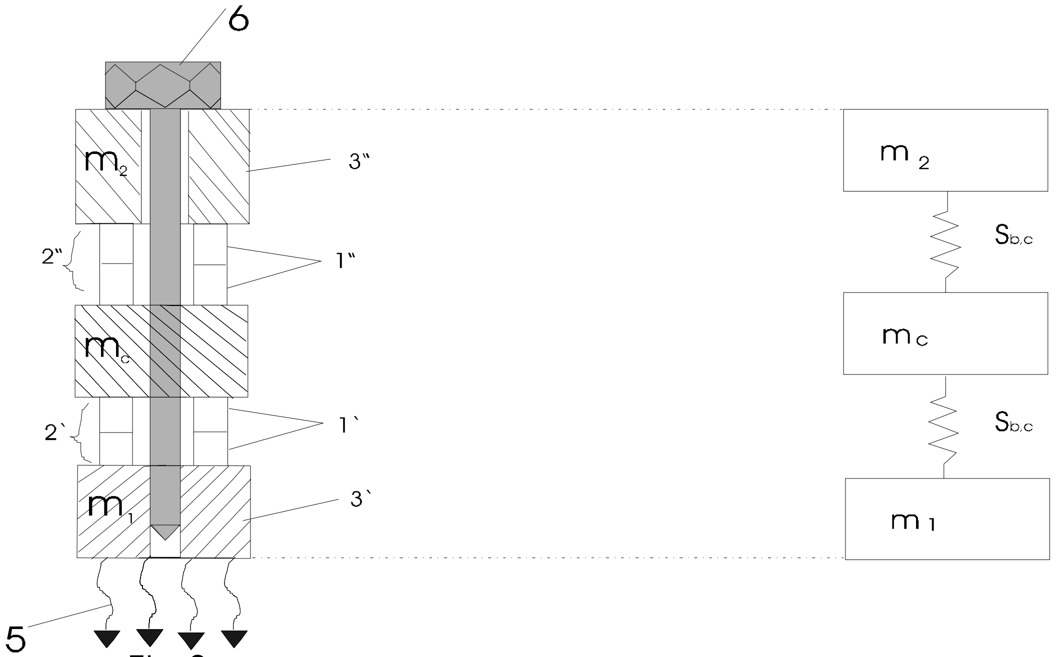

Fig.2.a

Fig.2.b

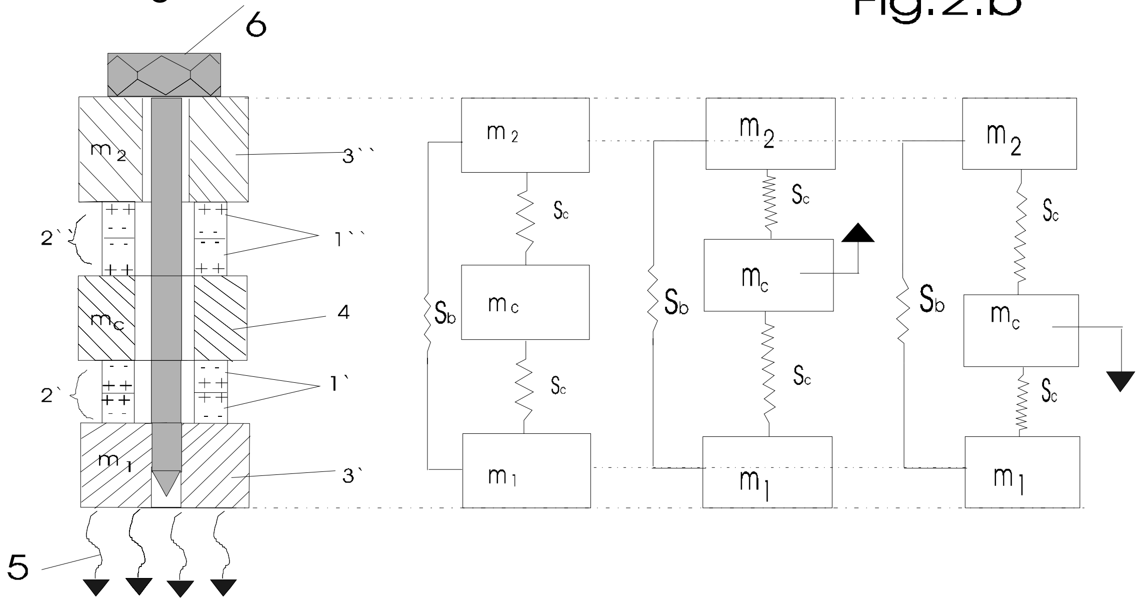

Fig.3.a Fig.3.b Fig.3.c Fig.3.d

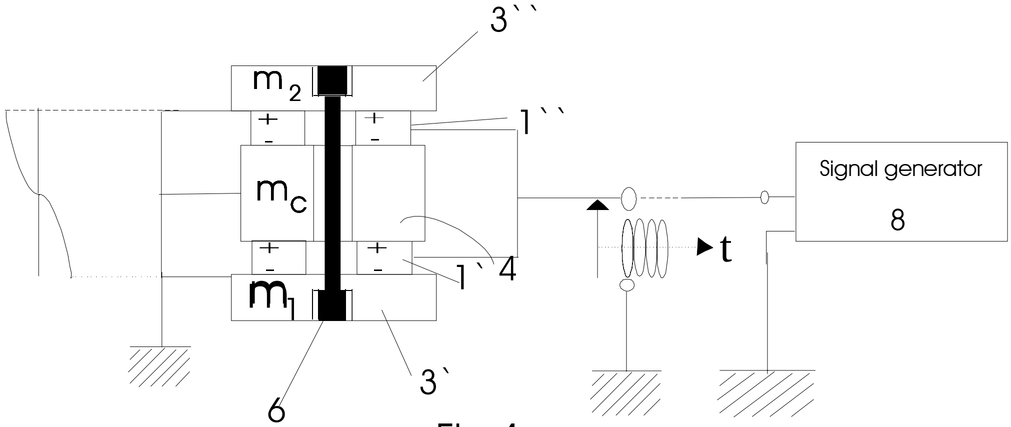

Fig.4

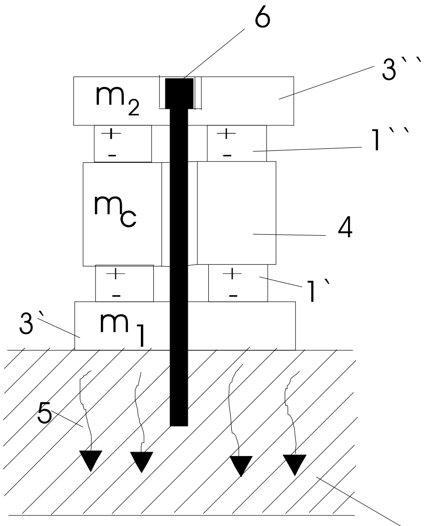

Fig.5

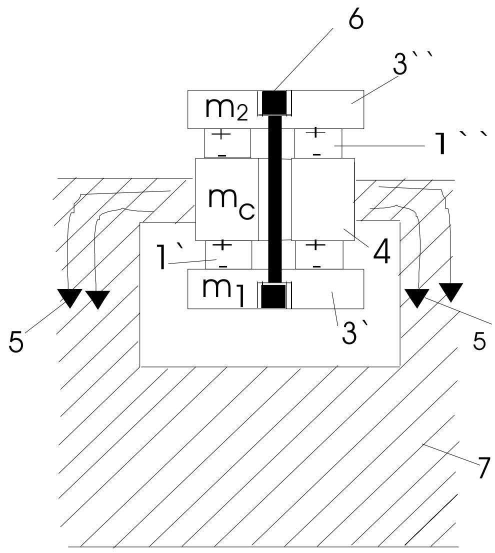

Fig.6

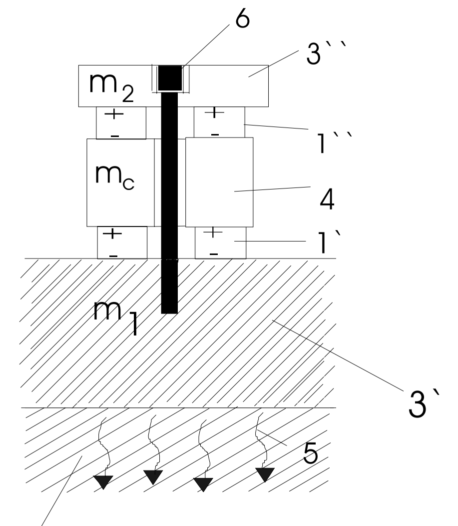

Fig.7

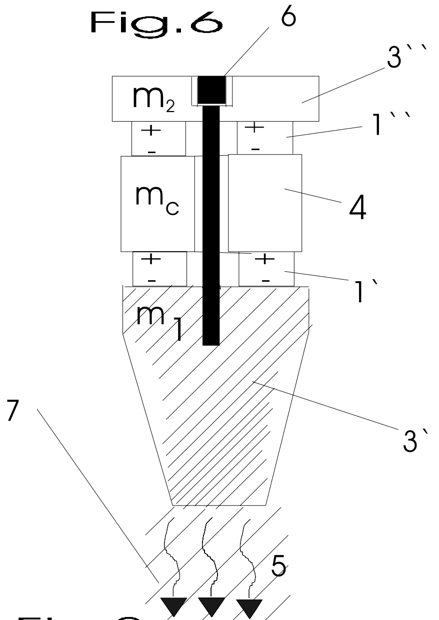

Fig.8

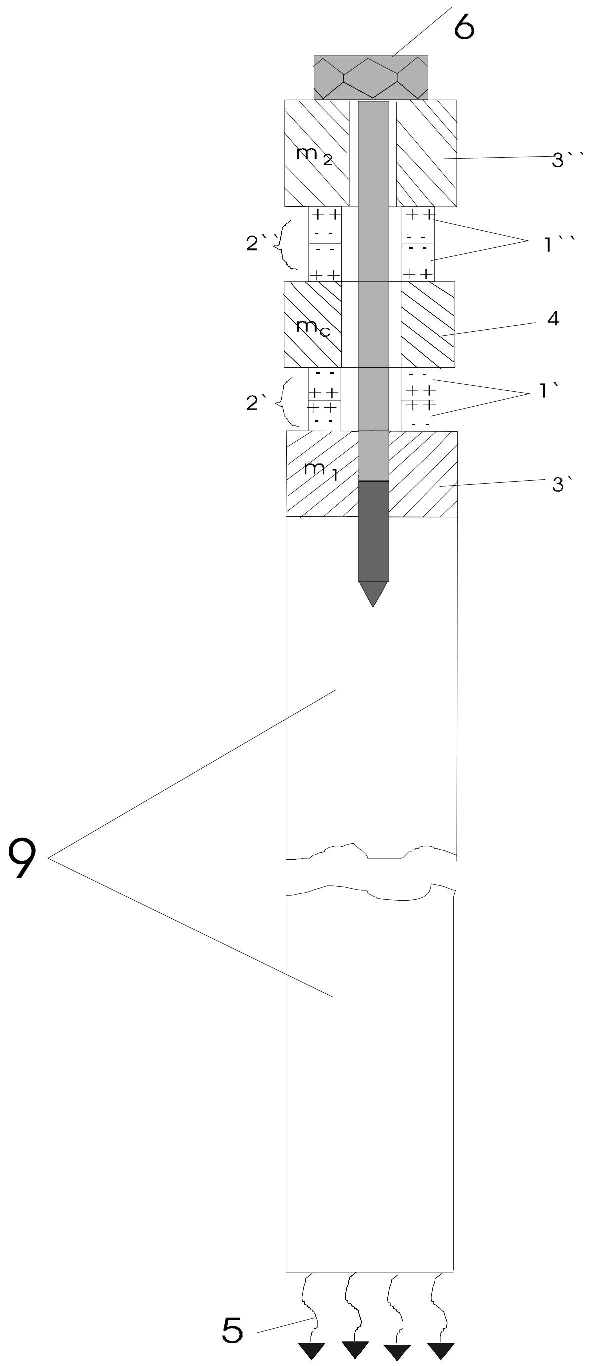

Fig.9

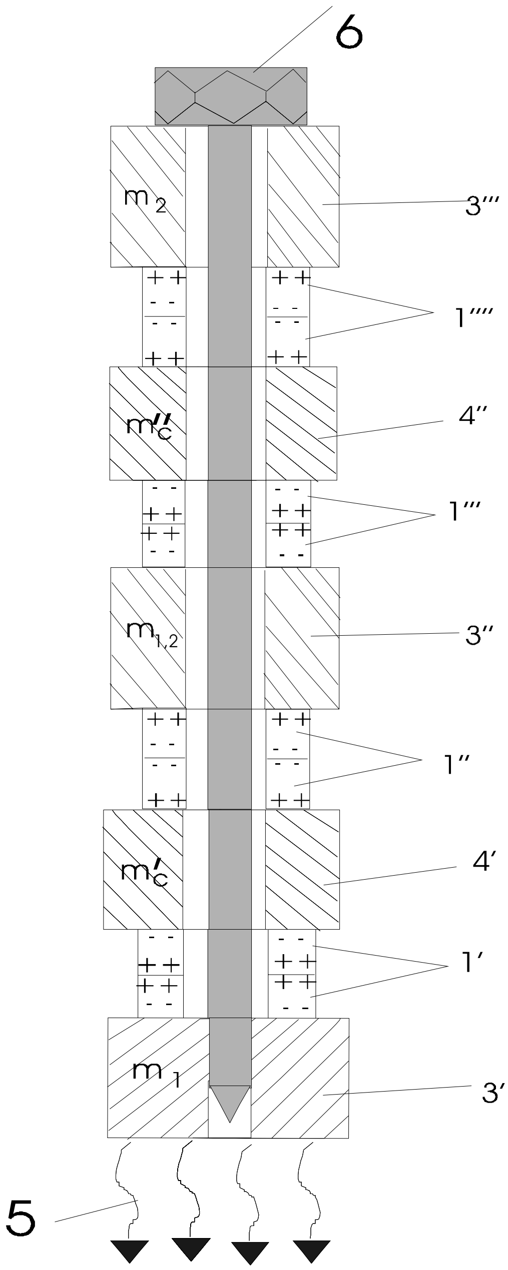

Fig.10.a

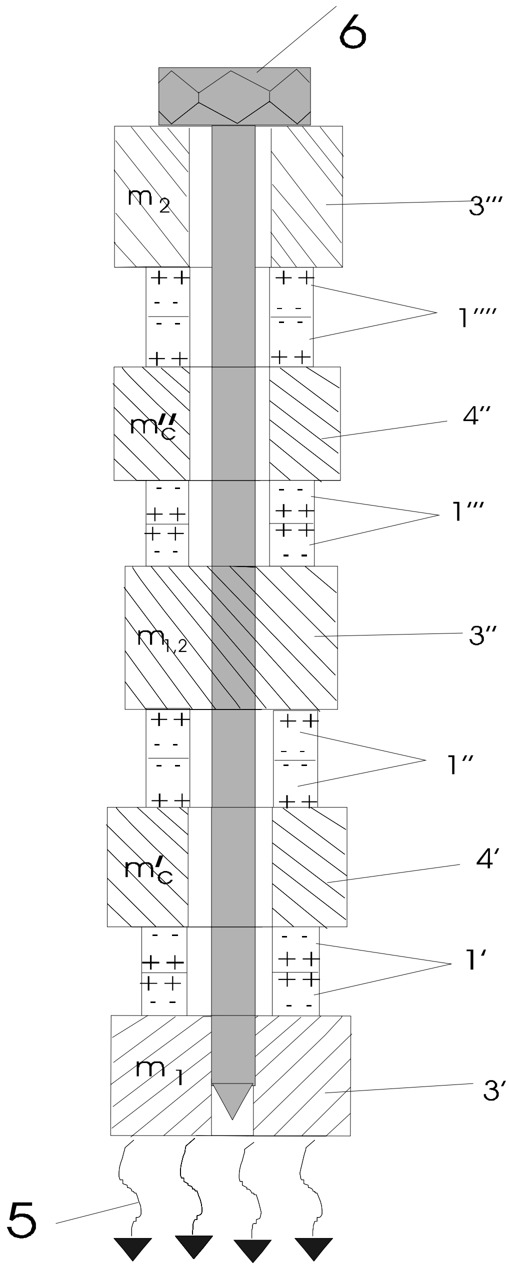

Fig.10.b

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