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MUSICAL INSTRUMENT UTILIZING PIEZOELECTRIC TRANSDUCER

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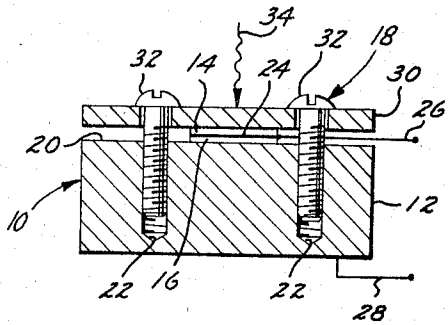


FIG. 1

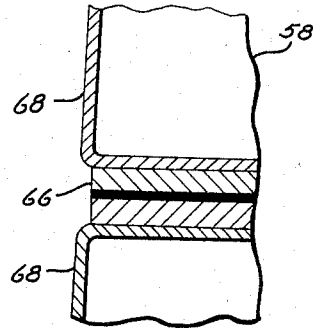


FIG. 4

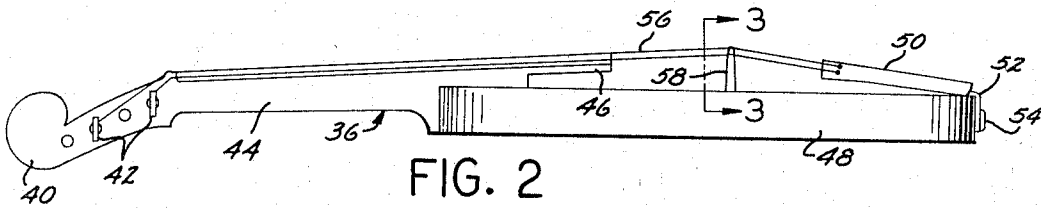


FIG. 2

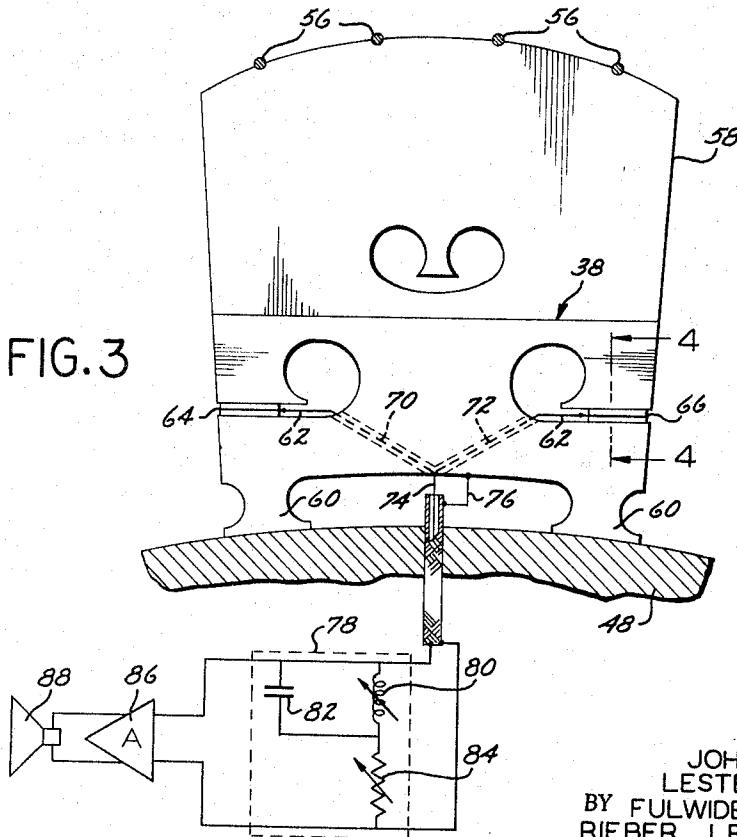


FIG. 3

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MUSICAL INSTRUMENT UTILIZING PIEZO-ELECTRIC TRANSDUCER

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14 Claims. (Cl. 84—1.16)

The present invention relates to a musical instrument, and more particularly to a musical instrument utilizing a transducer incorporating piezoelectric material to produce high fidelity output signals.

A variety of electromechanical transducers employing piezoelectric materials are shown in the prior art, but most of such transducers are not completely effective in faithfully converting mechanical movements or vibrations, such as that of vibratile portions of a musical instrument, into electrical output signals which precisely correspond to the character of the input vibrations. This lack of fidelity is primarily due to the nature of the mechanical coupling between the driving vibratile member and the piezoelectric material, the coupling frequently being so resilient or compressible that the mechanical movements or vibrations are damped or masked. Thus, it becomes impossible to obtain an alternating voltage output from the piezoelectric material exactly corresponding to the mechanical input. For example, undesirable damping occurs when the vibratile member is secured to the piezoelectric material by a compressible adhesive or by a deformable rod. Worse yet, such a coupling rod or similar element has its own resonant frequency or frequencies which can adversely affect the fidelity of the output. This is particularly apparent in transducers used in converting the mechanical vibrations of musical instruments into electrical signals for high fidelity recording purposes or the like.

This application is a continuation-in-part of our copending application, entitled, "Transducer," filed July 5, 1963, under Ser. No. 292,999. The benefit of that filing date is claimed for the common subject matter of the two cases. The present application discloses in more detail the adaptability of the invention to so-called non-solid musical instruments, such as a conventional violin having a usual resonant cavity.

It is an object of the present invention to provide a musical instrument of the aforementioned character and having a vibratile member mounted in association with the transducer in such a way that the vibrations of the member are faithfully converted into electrical signals exactly corresponding with the character of such vibrations. In one embodiment of the invention, the vibratile member forms a part of a clamping means which develops a compressive force upon the piezoelectric material in the same mode as that of the pressure variations developed by the vibrations of the vibratile member. The magnitude of the compressive force is adjusted so that the piezoelectric member is always in compression regardless of the amplitude of vibration of the vibratile member. In this manner, whether the vibratile member is driven one way or the other from its central or neutral position, the movement will provide an output signal. Stated another way, the piezoelectric material is pre-stressed by a clamping means which utilizes the vibratile member as a portion of the prestressing agency.

Another object of the invention is to provide a musical instrument of the aforementioned character incorporating a solid body or non-vibratile portion which, in association with a suitable clamping means, is operative to develop a compressive force upon the piezoelectric member without perceptibly or significantly affecting the mechanical motion of the vibratile member or of any adjacent structures.

Another object of the invention is to provide a musical

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instrument utilizing a vibratile member and transducer of the aforementioned character to provide high fidelity electrical output signals corresponding to vibrations of the vibratile member only. Accordingly, a recording of these signals would not include noise in the recording studio, conversation of the musicians and the like. This is true whether the musical instrument included a solid body or non-vibratile component, or a conventional vibratile or resonant body.

A further object of the present invention is to provide a musical instrument of the aforementioned character which includes a solid body or vibrationally inert or passive portion; a piezoelectrical plate of the thickness expander type; and pressure applying or clamping means for urging the piezoelectric plate against the passive member to develop a compressive force thereon at all times, the clamping means including a vibratile portion. The vibratile portion is actuated by vibration of the instrument's sound generating means, such as the strings of a stringed instrument, the reed of a reed instrument, or the lips of the player in the case of a brass instrument. Vibration of the vibratile portion alters the magnitude of the compressive force developed by the clamping means, the piezoelectric member always being in compression, whereby the full amplitude of vibration is converted into an electrical signal.

Another object of the invention is the provision of a bowed musical instrument, such as a violin, wherein at least a pair of piezoelectric members are utilized adjacent opposite sides of the string bridge, the piezoelectric members having different piezoelectric polarity orientations whereby, for example, movement of the string bridge to one side increases the compressive force on one member and decreases it on the opposite member, the resultant electrical signals of the two piezoelectric members thereby being cumulative.

An additional object of the invention is to provide a musical instrument of the stringed type, and in which the transducer is comprised of a plurality of piezoelectric members press-fitted in slots located at opposite sides of the string bridge whereby lateral vibrations of the strings, resulting from bowing for example, operate to rock the string bridge upon the piezoelectric members. It is a salient feature of this mounting arrangement that the piezoelectric members are always in compression because of the resilience of the bridge. Thus, when the string bridge rocks, the piezoelectric material in one slot is placed under greater compressive stress and the piezoelectric material in the opposite slot is placed under a lesser compressive stress, the oppositely disposed piezoelectric members preferably being characterized by opposite piezoelectric polarity orientations so that the output of the piezoelectric members is additive or cumulative. Such construction also renders the transducer relatively unresponsive to unwanted common mode vibrations such as those resulting from random frictional and mechanical forces acting upon the instrument body.

A further object of the invention is to provide a musical instrument of the aforementioned character in which the transducer output is applied to an electrical filter to modify the frequency character of such output. The electrical filter preferably takes the form of a formant filter which is adjustable to closely approximate the particular musical instrument concerned. As is well known, the formant filter is analogous to usual types of band pass filters which pass a relatively wide band of frequencies and reject other frequencies, but it is somewhat different in its capability for emphasizing certain frequencies and de-emphasizing others, according to the manner of its adjustment. The emphasis and de-emphasis is similar to the modifications effected by the resonant cavity of a violin, for example.

A further object of the invention is to provide a musical

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instrument of the aforementioned character, such as a violin, in which the transducer is productive of an alternating voltage which, after modification by a suitable filter network, is convertible into sound having the timbre, tonal qualities, and characteristics of another musical instrument, such as a cello.

Another object of the invention is to provide a musical instrument of the aforementioned character which is relatively simply fabricated and is dependable in operation.

Another object of the invention is to provide a transducer of the aforementioned character having response substantially limited to vibrations of a single mode or desired combination of modes.

Other objects and features of the invention will become apparent from consideration of the following description taken in connection with the accompanying drawings, in which:

FIG. 1 is an enlarged cross-sectional view of the transducer of a musical instrument according to the present invention;

FIG. 2 is a side elevational view of a violin incorporating the transducer of FIG. 1;

FIG. 3 is an enlarged elevational view taken along the line 3—3 of FIG. 2, together with a schematic showing of the accompanying electrical circuit; and

FIG. 4 is an enlarged view taken along the line 4—4 of FIG. 3.

Referring now to the drawings, and particularly to FIG. 1 thereof, there is illustrated a transducer 10 which comprises a substantially non-vibratile, acoustically inert, or vibrationally passive member 12, a pair of abutting piezoelectric elements 14 and 16, and clamping means 18 which continuously urges the piezoelectric elements 14 and 16 against the non-vibratile member 12 to maintain the elements 14 and 16 in compression at all times.

The non-vibratile member 12 may be constituted by a mass of lead or other passive material having relatively high inertia. The terms "non-vibratile," "acoustically inert" and "vibrationally passive" are relative and are intended to be inclusive of any material sufficiently passive or non-resonant at the frequencies to be transduced that its vibrations, if any, do not perceptibility or significantly affect vibrations of adjacent structures which are to be converted into electrical signals. Moreover, it is contemplated that such terms are inclusive of materials which may be inherently vibratile, but which are suitably braced and reinforced or damped so as to be substantially free of unwanted vibration or resonance. In general, these terms are used herein to describe a member, means, or body possessing (1) higher inertia, (2) greater damping at the frequencies desired to be transducer, or (3) higher mechanical resistance at such frequencies, than the vibratile portion of the clamping means operatively associated therewith.

As will be seen, the output of the transducer will correspond solely with the mechanical vibrations of the vibratile portion of the musical instrument with which the transducer is associated. Conversation of the performers, noises in the recording studio and the like are not part of the output and would not, for example, be a part of the recording of a musical performance. How this output is not affected by the non-vibratile character of the member 12 will be developed later in connection with a description of FIGS. 2-4. Likewise, there will later be discussed the nature of the output when the member corresponding to the member 12 is the resonant body of a fine violin, for example.

In the transducer 10, the non-vibratile member 12 is preferably made of lead and is characterized by a flat or planar upper face 20. It also includes a pair of threaded openings 22 for effecting securement thereof to the clamping means 18, as will be seen.

The piezoelectric elements 14 and 16 are each constituted by a thin, thickness expander slab or plate of polycrystalline electro-mechanically sensitive dielectric mate-

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rial, such as barium titanate or lead zirconium titanate. As is well known, the term "thickness expander" is indicative of the characteristic of a crystal plate to generate an electrical signal in response to mechanical vibration applied in the thickness mode, the plates 14 and 16 in the present instance converting these mechanical vibrations into electrical signals, as will be more particularly described hereinafter.

Each of the crystal plates 14 and 16 is provided on its opposite faces with conductive paint, metal, foil, metal sheet or the like to provide electrode surfaces by means of which the plates 14 and 16 are connected in an electrical circuit. In addition, the plates 14 and 16 are characterized by the same piezoelectric polarity orientations, with the electrodes thereof which are of like sign being placed in coextensive engagement to form a common electrode 24 to which an output lead 26 is secured. The opposite, outwardly disposed faces of the plates 14 and 16 carry the electrodes having polarity opposite that of electrode 24, and these are in engagement and consequent electrical contact with the non-vibratile member 12 and the clamping means 18, a ground lead 28 being secured to the member 12. With this arrangement, it will be apparent that application of a compressive force to the crystal plates 14 and 16 will result in an electrical output from each of the plates, which output is additive and in phase. If desired, only one crystal plate could be used, but the use of the pair of plates 14 and 16 conveniently isolates the common positive electrode 24 from electrical contact with the member 12 and the clamping means 18.

The clamping means 18 is constituted by an electrically conductive, elongated clamping member 30 having a pair of openings for slidably accommodating a pair of electrically conductive machine screws 32 which are threaded into the threaded opening 22 provided in the non-vibratile member 12. As will be apparent, rotation of the screws 32 in the proper direction urges the flat underside of the clamping member 30 into forceable engagement with the outer face of the plate 14, developing a compressive force upon both of the plates 14 and 16 by squeezing them between the members 30 and 12.

The clamping member 30 transmits vibrations to the plates 14 and 16, and may itself constitute the vibratile member which is directly mechanically agitated, or it may be intimately connected to vibratile member for vibration by such member. In either event, the clamping member 30 itself constitutes a vibratile member which is vibrated by the input mechanical movements, as schematically indicated by the numeral 34 in FIG. 1. Thus, in a missile structure, for example, the clamping member 30 may be the element whose vibrations are to be determined, or the clamping member 30 could be welded or otherwise rigidly secured to the structural member of interest for vibration in sympathy therewith. However utilized, the vibratile member is always urged toward or against a non-vibratile member by a form of clamping means incorporating or securely fixed to the vibratile member.

The clamping screws 32 are adjusted to apply a constant compressive force to the crystal plates 14 and 16, regardless of the amplitude of the vibration of the clamping or vibratile member 30, so that the plates 14 and 16 are always prestressed. That is, a mechanical bias is exerted on the plates along an axis substantially normal to the thickness or electrode faces of the plates, which develops a compressive force, whose magnitude is altered by the mechanical vibrations of the vibratile member 30.

Initial tightening of the clamping screws 32 causes the crystal plates 14 and 16 to develop an output voltage, but this soon is dissipated so that the plates reach a neutral state of no voltage output. Thereafter, vibration of the vibratile member 30 in either direction along an axis normal to the thickness faces of the plates is operative to increase or decrease the existing compressive force and thereby develop an output electrical voltage.

With this arrangement there is no slack, "play," resilience, or deformation in the transducer components, and mechanical vibrations are faithfully converted by the transducer 10 into an alternating voltage output substantially free of spurious vibrations and substantially exactly corresponding to the character of the mechanical input vibrations. In summary, sustained application of a compressive force on the crystal plates 14 and 16, in the same mode as that of the mechanical vibrations applied by the vibratile member 30 to drive the plates 14 and 16, is productive of highly accurate transducer response.

Musical instruments made according to the present invention include members of the viol family, the guitar, the piano, the flute, and also different reed, percussion, and brass instruments.

Referring now to FIGS. 2 through 4, there is illustrated a musical instrument constituting a violin 36 having a transducer 38. The violin 36 is similar to any ordinary violin in that it includes a scroll 40, string-adjusting pegs 42, and a neck 44 upon which a finger board 46 is mounted. However, according to one version of the present invention, the body portion or resonator box of the usual violin is omitted and a solid or non-vibratile body portion 48 is provided instead. The body portion 48 could be made hollow, if desired, provided it is braced, reinforced, or damped in such a manner as to be substantially non-vibratile or non-resonant at those predetermined frequencies which it is desired to transduce. Thus, the resonating characteristics of usual violin bodies are not present. This eliminates the amplification and modification of violin string vibrations which are provided by usual violin bodies.

More particularly, the sound amplifying or resonant chamber of a conventional violin is characterized by certain resonant vibratory frequencies, the violin thus being sympathetically responsive to certain tonal vibrations more than others and consequently amplifying those tonal vibrations to a greater degree than others. Since it is only a "perfect" violin that will exactly modify the string vibrations in the manner sought by violin enthusiasts, most violins will suffer some imperfection in this regard.

This problem is avoided by the violin 36 since there is no resonant body portion. Only the pure tones of the violin string vibrations are transduced. Thus, the violin 36 is utilized primarily as a support for the strings. The string vibrations are connected by the transducer 38 into an alternating voltage output which is modified by a filter network, as will be seen, to provide the characteristic violin sound or, with somewhat different modification, to provide the sound of some other member of the viol family.

A conventional violin tail piece 50 having a loop 52 fitting over a button 54 secures the ends of a plurality of tensioned, vibratile strings 56 to the violin 36, the opposite ends of the strings being attached to the string-adjusting pegs 42. In addition, the strings 56 are supported intermediate the pegs 42 and the tail piece 50 within suitable notches provided in the arcuate upper edge of a usual string bridge 58, which is made of maple wood or the like, the feet 60 of which rest upon the solid body portion 48, as best illustrated in FIG. 3.

The string bridge 58 is, like the string bridges of conventional violins, vibratory in a transverse direction in response to bowing of the strings 56, the string bridge in effect rocking back and forth upon its spaced-apart feet 60. Thus, the string bridge 58 constitutes a vibratile member itself, acting as a transmitter of the vibrations of the strings 56 in a transverse mode.

More particularly, the pair of slotted openings in the opposite sides of the usual violin string bridge are slightly enlarged in the bridge 58 to provide openings 62, and a pair of piezoelectric slabs or plates 64 are forcibly pressed or wedged in one of the openings 62, and another pair of piezoelectric slabs or plates 66 is similarly pressed

in the other slotted opening 62. The resilient maple wood of the bridge 58 exerts a very positive, relatively high constant or continuous compressive force upon the plates 64 and 66, the magnitude of this compressive force preferably being sufficiently great that the transverse vibrations of the string bridge 58 are never enough to completely relieve all compressive stress on the plates.

The plates 64 and 66, except for polarization orientation, as will be seen, are identical to the crystal plates 14 and 16 of the transducer 10 of FIG. 1.

An electrically conductive coating or paint 68 is applied to both faces of the lower portion of the string bridge 58, and also the edge margins defining the slotted openings 62, as best illustrated in FIG. 4. The thickness of the paint 68 is greatly exaggerated for clarity. In addition, the opposite faces of the crystal plates 64 and 66 are coated with a conductive paint or similar material to provide electrodes similar to the electrodes on the crystal plates 14 and 16.

Each of the pair of crystal plates 64 is characterized by the same piezoelectric polarity orientation, and the plates 64 are arranged so that a pair of the electrodes thereof of like sign are inwardly oriented in engagement with each other. An output lead 70 is attached to the common electrode thus formed, which is assumed for the present description to be positive, although it could be negative if desired.

The crystal plates 66 are also characterized by a common piezoelectric polarity orientation, but the orientation is the opposite of that of the plates 64. The plates 66 are arranged so that a pair of the electrodes thereof of like sign are inwardly oriented in engagement with each other. However, the sign of these inwardly oriented electrodes is the opposite of the inwardly-oriented electrodes of the plates 64. Thus, in our example, if the inwardly oriented electrodes of the plates 64 are positive, the corresponding electrodes of the plates 66 would be negative, and are coupled together and connected to an output lead 72.

The output leads 70 and 72 are disposed within downwardly convergent drilled passages provided in the string bridge 58, and the conductive point 68 on the opposite faces of the bridge 58 serves as electrical shielding therefor. The leads 70 and 72 are connected together to a common output lead 74 which forms a part of a shielded cable whose ground shield is connected by a ground lead 76 to the conductive paint 68 on the string bridge. The ground circuit is completed from the ground lead 76 to the negative electrodes of the crystal plates 64 and 66 through the conductive coating 68.

Although the plates 64 have the same polarity orientation, and the plates 66 have the same polarity orientation, the plates 64 have a different piezoelectric polarity orientation compared to the crystal plates 66. Thus, as the string bridge 58 is transversely moved in one direction, the plates 64 will experience an increase in compressive force thereon, for example, and the plates 66 will experience a reduction in compressive force thereon, but the resulting electrical outputs from the plates 64 and 66 will be of the same sign and in phase, and thus cumulative. In addition, simultaneous application of an additional and equal compressive force on the plates 64 and 66 will result in no electrical output.

The violin 36 is played in the same manner as one would play a conventional violin, the player bowing the strings 56 to effect the desired transverse vibratory movement of the string bridge 58, but in the violin 36 the vibrations of the string bridge 58 alter the compressive forces upon the plates 64 and 66 to provide an alternating voltage output. Thus, the bridge 58 not only constitutes a clamping means for exerting a constant compressive force upon the plates 64 and 66, but also constitutes or includes a portion serving as a vibratile member for altering such compressive force in accordance with the string vibrations. The vibratile bridge 58 presses or urges the plates 64 and 66 toward the solid body 48, which acts as a vibration

damping means to isolate the bridge 58 and plates 64 and 66 from spurious vibrations not generated by the strings 56. It is for this reason that the solid body 48 is substantially non-vibratile or passive. Its relatively high inertia affords highly efficient damping. Thus, it is seen that the non-vibratile member 12 and the clamping means 18 of FIG. 1, including the clamping or vibratile member 30 thereof, have their counterparts in the non-vibratile violin body 48 and the string bridge 58, the bridge 58 acting as a clamping means and as a vibratile member.

Although the location of the plates 64 and 66 in the openings 62 is preferred, the plates could also be clamped between the violin body 48 and the pair of bridge feet 60. This has been tried, and operates satisfactorily.

The electrical output of the crystal plates 64 and 66 is applied by the leads 74 and 76 to an electrical load or filter system 78 which may take a variety of forms to modify the output of the violin 36, as is well known to those skilled in the art. The system used should operate to emphasize, modify, or eliminate certain frequencies to produce an overall sound having the timbre and tonal character of the musical instrument desired, in this case a violin. The preferred form of filter system 78, and which has operated satisfactorily, is that which is known as a "formant" filter. In its simplest form, as best illustrated in FIG. 3, the formant filter includes a variable inductance 80 and a capacitor 82 connected in parallel, and a variable resistance 84 connected in series with the inductance 80 capacitor 82 circuit. The formant filter thus constitutes a parallel resonant band pass form of filter in which the resistance 84 is increased to broaden the band pass and reduced to narrow the band pass. The inductance 80 is adjusted to upwardly or downwardly shift the frequency band passed. Such adjustments are made until the precise tonal character desired is achieved, the adjustments being essentially empirical. It has been found that the violin 36 can be tuned not only as a violin, but that with proper strings and with a suitable formant filter it can be tuned one octave below the normal tuning of a violin to provide a tone having a timbre and quality like that of a cello. It should also be noted that a similar instrument having dimensions and string length substantially the same as that of a viola can, by appropriate choice of strings and formant filter, be tuned two octaves below the normal tuning of a violin and made to provide a tone having timbre similar to that of a Double-Bass.

The output of the filter system 78 is applied to a suitable amplifier 86 and the amplified signal then utilized to drive a loudspeaker 88, it being apparent that the output of the filter system 78 could also be applied to a recorder or broadcast system or otherwise utilized, as desired.

The non-vibratile, acoustically inert, or vibrationally passive solid body portion 48 provides a member which possesses such order of mechanical inertia at the frequencies to be transduced as will substantially eliminate the transfer of any unwanted vibration or resonance from such member to the associated piezoelectric members. This avoids the undesirable tonal characteristics normally imparted to the sound of poor-quality instruments by the hollow body portion or resonator box of such instruments and provides extremely faithful amplification of the vibrations of the bridge 58 resulting from vibrations of the strings 56. The consistently pure tone producible with this "solid-body" type of instrument is greatly superior in timbre and musical quality to that obtainable from the average stringed instrument of conventional design and can be approached only by rare instruments of uncommon tonal quality and high cost.

Several additional advantages are realized as a result of the solid-body construction. One benefit is the increased ruggedness of the instrument; another is the minimal acoustic coupling provided, which renders the instrument valuable for practice use, either with or without amplification, by monitoring of the output through headphones or the like. Still another advantage is the ability to pro-

vide such instruments with any desired body shape, decorative finish and ornamentation without substantially affecting the sound quality or characteristics.

Instruments have been constructed according to the present invention which, by reason of lacking any dependency upon the cubic volume of air space within the body chamber to effectuate sound reinforcement, are able to provide efficient amplification of string vibrations encompassing fundamental frequencies which significantly transcend the normal range possible for ordinary instruments of similar physical dimensions.

However, in certain instances important advantages result from the use of transducers of the type described above, but in association with very high quality musical instruments of otherwise conventional design and construction. The much-desired tonal qualities of fine instruments apparently results from the selective discrimination which the instruments provide with respect to the frequency content and relative amplitude of partials comprising the acoustically-reinforced formant structure of the string vibrations. In general, this pattern is less perfect than the typical formant structure of a tone produced by utilizing the transducer output of a solid-body instrument, but it is the unique character of this imperfection which, in large measure, defines the "personality" of a fine instrument. This "personality" is captured by the associated transducers, while yet room noises and conversation is not picked up.

The installation of transducers constructed according to the present invention to operate in association with a conventional violin, for example, is basically simple and can be accomplished in little time without modification of the instrument. They can be quickly and easily installed and removed without damage to the instrument by placement in a slot of the bridge, such as the slotted openings 62 previously described, or beneath a foot of the bridge. A pair of transducer element assemblies may be used if desired, one assembly at each side of the bridge, or a single such assembly may be used. The maintenance of continuous compressive force upon the piezoelectric members of the transducer is observed, and the transducer output signal is appropriately modified by electrical filter means as mentioned in connection with the "solid-body" instrument configuration.

From the foregoing description, it will be apparent that by utilizing piezoelectric material, such as a thickness expander plate of barium titanate or lead zirconate-titanate, and applying a compressive force to the material by interposition between a vibratile element and another element, the material is adapted to convert mechanical movements of one or both of such elements into an alternating electric voltage corresponding substantially exactly to the character of the driving mechanical vibrations. Although a violin application has been described, there are other musical instruments equally adapted for association with the transducer of the present invention. Thus, in a trumpet the instrument mouthpiece would be one element, and the piezoelectric material would be held under compressive force between such element and another element characterized by a configuration suitable for contact with the mouth of the player. Likewise, in a reed instrument such as a saxophone the piezoelectric material is held under compressive force between the vibratile member 30, in this case the reed of the instrument mouthpiece, and an associated element.

Accordingly, the several embodiments of the invention which have been described are illustrative only, and it will be understood that various modifications and changes in structure of such embodiments may be made, and other embodiments or forms introduced, without departing from the intended spirit or scope of the present invention as herein disclosed. All modifications and forms of this invention that may be apparent to those skilled in the art are reserved, and the invention is not to be limited or in any manner restricted to the specific details or embodi-

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ments above set forth, being limited only by the language and scope of the appended claims.

We claim:

1. A stringed instrument comprising:
means including a body; 5
a pair of piezoelectric members providing an alternating voltage output when pressure variations are applied thereto; and
- a string bridge mounted to said body and including a pair of oppositely disposed openings within which said piezoelectric members are wedged whereby said bridge develops a continuous compressive force upon each of said piezoelectric members, and whereby vibrations of said string bridge continuously alter the magnitude of said compressive force to effect an alternating voltage output of said piezoelectric members corresponding to the character of said vibrations. 10
2. A stringed instrument according to claim 1 wherein said body is substantially acoustically inert.
3. A stringed instrument according to claim 1 wherein each of said piezoelectric members is of opposite piezoelectric polarity orientation. 15
4. A stringed instrument according to claim 1 and including electrical filter means coupled to said pair of piezoelectric members and operative to modify the frequency character of said alternating voltage output. 20
5. A stringed instrument according to claim 1 and including formant filter means coupled to said pair of piezoelectric members and operative to modify the frequency character of said alternating voltage output. 25
6. A stringed instrument according to claim 1 wherein each of said piezoelectric members includes a pair of piezoelectric elements having the same piezoelectric polarity orientation, one pair of said piezoelectric elements being of a piezoelectric polarity orientation opposite that of the other pair of piezoelectric elements. 30
7. A musical instrument comprising:
a body;
piezoelectric means adapted to provide an alternating voltage output when pressure variations are applied thereto in the thickness mode; and 35
clamping means, including a vibratile member, mounting said piezoelectric means in association with said body and applying continuous compressive force to

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said piezoelectric means in the same mode as that of said pressure variations whereby vibrations of said vibratile member continuously alter the magnitude of said compressive force to effect an alternating voltage output of said piezoelectric means corresponding to the character of said vibrations.

8. A musical instrument according to claim 7 wherein said vibratile member is the string bridge of a stringed instrument.

9. A musical instrument according to claim 7 wherein said body is the mouthpiece of a brass instrument and said vibratile member is contactable by the mouth of the player.

10. A musical instrument according to claim 7 wherein said vibratile member is the reed of a reed instrument. 15

11. A musical instrument according to claim 7 and including electrical filter means coupled to said piezoelectric means and operative to modify the frequency character of said alternating voltage output.

12. A musical instrument according to claim 7 and including formant filter means coupled to said piezoelectric means and operative to modify the frequency character of said alternating voltage output.

13. A musical instrument according to claim 7 wherein said piezoelectric means is a thickness expander plate of piezoelectric material. 25

14. A musical instrument comprising:

a body including a vibratile first portion and a second portion which is less vibratile than said first portion; and

piezoelectric means adapted to provide an alternating voltage output when pressure variations are applied thereto in the thickness mode, said piezoelectric means being disposed between said first and second portions and under continuous compressive force therebetween whereby vibrations of said first and second portions continuously alter the magnitude of said electric means corresponding to the character of said vibrations. 30

No references cited.

ARTHUR GAUSS, *Primary Examiner*.

J. JORDAN, *Assistant Examiner*.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,325,580

June 13, 1967

Lester M. Barcus et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 10, line 37, after "said" insert -- compressive force to effect an output of said piezo---.

Signed and sealed this 16th day of July 1968.

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

EDWARD J. BRENNER

Commissioner of Patents