This invention relates to musical instruments of the stringed variety, and more particularly to instruments of such nature in which the vibrations of the strings are transformed by piezoelectric transducers into electrical signals capable of amplification and subsequent reproduction of the sound produced by such instruments.

Musical instruments of the type to which this invention pertains are frequently referred to as being electrified or electrically amplified. The quality of the music produced by electrified musical systems is determined in large part by the nature of the electrical oscillations delivered by the pickup forming a part of the system. Unless the pickup can convert the vibrations of the strings into electrical oscillations without losing important components and without introducing objectionable extraneous signals, the quality of the music will suffer. Many different types and designs of pickups have been proposed heretofore. Some artists prefer to employ an acoustical pickup provided by placing a microphone close to, on, or inside of the musical instrument. The magnetic type of pickup has also been adopted and used in substantial numbers. Piezoelectric type pickups have been suggested from time to time, but have not come into extensive use.

In the use of acoustical pickups, feedback resulting from the reintroduction of amplified sound from the system back into the pickup end of the system poses a constant and serious problem. One of the serious limitations encountered in the use of pickups of the magnetic type is that extraneous signals are inevitably introduced into the system. The electrical coils forming a part of the magnetic pickup have some of the characteristics of loop antennas, and it has been found that the pickups are susceptible, to stray radiation produced, for example, by neon signs and even by alternating current distribution systems.

Piezoelectric pickups, on the other hand, have frequently had other disadvantages associated with them. For example, it is not uncommon for such pickups to be substantially less responsive to string vibrations in one plane than to one vibration in another plane. The effect of variations in response of this nature is to degrade the quality of the electrical signal produced by the system and therefore to reduce the fidelity of response in an electrically amplified musical system. In addition, the signal produced by piezoelectric pickups generally has tended to be of such a low level that the amplifier used in conjunction with the pickup is required to possess a very large gain to reproduce the input signals effectively. Furthermore, although piezoelectric pickups are not, in and of themselves, especially sensitive to ambient stray radiation, the magnitude of induced electrical signals from stray sources is often quite substantial in comparison with the primary signal produced by the pickup. Consequently, hum and other background noise are significant factors to be considered in the design and use of piezoelectrically responsive electrically amplified systems.

It is a general object of the present invention to overcome the objections and disadvantages noted above and to provide musical instruments with improved pickup means capable of accurately converting mechanical vibrations into electrical signals.

Another object of the invention is to produce electrified musical instruments of the stringed variety which, without requiring alteration of the basic character of the instruments, are capable of generating high-gain electrical signals accurately representing the sound quality produced by the instrument.

A still further object of the invention is to provide musical instruments having piezoelectric pickup means especially insensitive to stray radiation effects.

Yet another object of the invention is to provide a stringed musical instrument with a piezoelectric pickup possessing maximum sensitivity with respect to vibrations of the strings and minimum sensitivity with respect to vibrations of other parts.

It is still another object of the invention to provide a piezoelectric transducer assembly of simple construction and high output which is easily integrated in and adapted for use with a wide variety of musical stringed instruments.

By way of a brief summary of one preferred embodiment of the invention, a classical guitar, for example, is provided with a unique bridge arrangement having attached thereto a plurality of cylindrical piezoelectric pickup elements, one for each string of the guitar. These piezoelectric elements each have an axial aperture extending therethrough from end to end. They are coated on the inside, with an electrically conductive layer and on the outside with a second electrically conductive layer.

The arrangement of these layers is such that the outer one shields the inner and electrical potentials are generated between the two layers in response to variations in stress on the element. Each string of the guitar passes through the axial aperture of one of the transducer elements without contacting the interior thereof and is fastened, under tension, of course, to a cap attached to the opposite end of the transducer. The effect of this arrangement is to place the transducer under compression as a result of the tension of the string. String vibrations are translated into variations in compression of the transducer element to produce, in turn, electrical signals across the conductive layers accurately responsive to the vibrations of the string regardless of the plane in which such vibrations occur. Although the invention is not to be limited except by the claims appended hereto, further details of the invention as well as additional objects and advantages thereof in differing embodiments may perhaps be better understood in connection with the following more complete description taken together with the accompanying drawings wherein:

FIGURE 1 is a perspective view of a classical guitar modified in accordance with this invention and provided with a unique piezoelectric bridge assembly;

FIGURE 2 is a longitudinal cross-sectional view through the bridge assembly of FIGURE 1 and illustrating the relationship between a vibratable string and its associated transducer;

FIGURE 3 is a view similar to that of FIGURE 2 showing an alternate construction of a transducer assembly in accordance with the present invention;

FIGURE 4 is a perspective view of a contrabass constructed in accordance with this invention with transducer elements mounted thereon at the lower end of the strings beyond the bridge.

In FIGURE 1 the invention is illustrated as being embodied in a classical guitar having a flat body 10 and a long fretted neck 11. The instrument strings 12 are stretched over head nut 13 and wrapped about adjustable tuning keys 14 in the head 15 of the instrument. At their opposite ends the strings 12 terminate in a modified bridge 16 bonded to the sound board 17 of the guitar body 18. It is in the bridge assembly that the principal alteration of the instrument is made in this particular embodiment in the invention.

As best seen in the enlarged cross-sectional view of
FIGURE 2, the bridge 16 comprises an elongated L-shaped bracket 20 affixed at its base to the sound board 17 of the instrument and having an upstanding ridge 21 thereon. The material of which structural element 20 is composed is not critical, although in the embodiment illustrated it is shown to be of metal. Some will undoubtedly prefer to employ traditional wood for this element, such as ebony or rosewood. Mounted on the upstanding ridge of the bracket is a row or series of piezoelectric transducers 22. The basic material of these elements is, of course, a crystal material which generates surface potentials when the crystal is subjected to mechanical stresses or strains. These piezoelectric transducers in this illustrated embodiment are cylindrical and each has an aperture 23 extending therethrough. Their axes are aligned with those of the strings 12. The transducers bear at one end of their apertures against the bracket structure with their opposite ends extending in a direction away from the head of the instrument. Each transducer element has at its opposite end a metallic cap 24 with a small axial aperture therethrough. The larger diameter aperture 23 of the transducer element communicates with a corresponding aperture 25 in the upstanding ridge 21 of the bracket or bridge 20. The transducer is held captive inside the cap by a clamp ring 26 threaded into the bracket 20 about the transducer and bearing against the flange 27 thereon.

Each of the musical strings of the guitar in this embodiment extends through the communicating apertures in the upstanding ridge, the cylindrical piezoelectric transducer, and the metallic cap, to a terminal knot 28 or other enlargement at the end. When the strings are brought to pitch by adjustment of the tuning keys 14 at the head of the instrument, the vibratable length of each musical string is defined by that portion between the head nut 13, as seen in FIGURE 1, and the cap 24 on its transducer element. It is to be especially noted that the passage of each string axially through its associated transducer to bear against the opposite end of the transducer results in the transmitting the whole tension of the string into an axial compressional force on the transducer. Vibrations of a string result in variations of the string tension and, hence, of the compressional force on the transducer, causing variations in the potential on the surface of the piezoelectric crystal.

Each transducer includes a conducting surface 30, preferably silvered, lining the interior of its axial aperture and another conducting surface 31 on the exterior thereof constituting the conducting the external surface. Between these conducting surfaces, potentials of varying amounts are generated in response to the mechanical forces on the element. The external conducting surface 31 is grounded through clamp ring 26 and bracket 20 to the external conductor 32 of a shielded cable. An internal conductor 33 of the cable passes insulated through the bracket and into electrical contact with the internal conducting surface 30. The shielded cable conductors transmit the signals generated by the transducer to an amplifier for reproduction and/or recording of the signal output of the instrument.

As a consequence of the use of a transducer arrangement described, the signal output of each transducer accurately reflects the frequency and amplitude of vibration of its associated string, regardless of the plane or planes in which the string vibrates. This is because the piezoelectric pickup is sensitive almost exclusively to variations in axial string tension during the vibrations of the string, rather than to the minute lateral movements which naturally take place at the end of the vibrating length of the string. With this construction, the signal output of the transducer is substantially greater than with prior constructions for various reasons, partly because the transducer is indeed equally sensitive to string vibrations in all planes. Also, since the entire string tension is transmitted to the transducer rather than only a geometric component thereof as in prior arrangements, the transducer is enabled to respond to the whole variation in tension rather than to only a portion thereof.

Another significant advantage of the described construction is that inherent shielding properties which result in protecting the piezoelectric pickup against the introduction of spurious signals induced by stray radiation. The external conducting surface 31 on the transducer element surrounds and isolates the internal conducting surface from such radiation. Consequently, it is the external conducting surface which is selected for grounding through the exterior of the shielded connecting cable. The internal conducting surface 30 is considered to be the hot terminal of the transducer. Because of its shielded construction, not only does the described transducer arrangement generate a high level signal output, but its output signal also has a high signal-to-noise ratio.

In FIGURE 3 is shown an alternate construction of a transducer or pickup for stringed musical instruments according to the present invention. In this illustration the parts of the transducer assembly which correspond to those of FIGURE 2 are identified by the same reference numerals with primed accents added. It can be seen that the piezoelectric crystal 22 in this embodiment is in the shape of a truncated cone with an axial aperture therethrough. The body of the transducer is again provided with conducting surfaces 30' and 31' inside and out as in the previous example. The shape illustrated in this figure provides a somewhat greater structural rigidity for the piezoelectric element than is provided by a simple cylindrical configuration. Because of the symmetry of the transducer about its axis and because of the axial compression exerted upon it by the vibratable string, the transducer is equally responsive to string vibrations regardless of the plane or planes in which they occur. If it is desired to add extra shielding for the interior conducting surface of the transducer, this may be accomplished by restricting the aperture 25' in the metallic bridge through which the vibratable string 12 extends. Alternatively, if the bridge is constructed on a nonconductor, a simple perforated diaphragm of metal foil may be provided across the larger diameter of the aperture in the cone-shaped transducer. In such a case the additional metal shielding should, of course, be grounded.

In FIGURE 4 another form of the invention is shown in a contrabass of generally traditional construction. In accordance, the form and operation inducing the contrary signal output.

Each of the four strings 40 of the contrabass passes under tension from the pegs 41 in the scroll 42 at one end of the instrument and over the bridge 43 on the sound board 44 to terminate at the string holder 45. In this embodiment, the piezoelectric pickup arrangement is not a part of the bridge structure but is incorporated in the string holder at its upper terminus. Each of the four strings 40 of this instrument passes axially through a symmetrical hollow transducer element 46 attached by brackets 47 to the bridge. Each string bears against the opposite end of a transducer element and places it under compression as previously described to generate a signal output in similar manner.

These transducers 46 are clearly mounted beyond the end of the vibrating length of the string. Prior transducers which have depended for their effectiveness upon minute lateral movements at the end of a vibrating length of string would prove useless at such a point. Nevertheless transducers constructed in accordance with the principles of this invention function effectively beyond the bridge because they respond to variations in the tension in the string produced by its vibrations. The signal output of a transducer located beyond the
bridge is admittedly not as strong as it would be if the transducer were mounted in a bridge structure at the exact end of the vibrating length of string, because of the absorption of a certain amount of energy by the bridge interposed between the vibratable length and the transducer. Nevertheless the signal output of transducers constructed in accordance with this invention is more than adequate for amplification purposes, and the ease of adapting an existing musical instrument is a significant advantage.

While certain specific examples of the invention have been shown and described, it should be understood that these preferred embodiments are offered for purposes of illustrating the principles of the invention and their application. Additional modifications of the invention will doubtless occur to those skilled in the art to which this invention pertains and it will be understood that the invention may be embodied in a wide variety of strung musical instruments. The application of this invention in no way depends upon any special magnetic or electrically conductive properties of the strings of the instrument. It is therefore intended that the appended claims should cover all such modifications as fall within the true spirit and scope of the invention in its broader aspect.

What is claimed is:
1. A strung musical instrument comprising:

   at least one vibratable string for producing musical tones;

   means for placing said string under axial tension;

   an axially symmetrical piezoelectric transducer disposed at one end of said string with its axis of symmetry aligned with that of said string, said transducer being placed under axial compression by the tension in said string;

   said transducer including a pair of spaced apart conductive elements in contact with portions of the surface thereof;

   and electrical conductors in contact with said conductive elements for deriving electrical signals therefrom in response to variations in tension of said string.

2. The combination of claim 1 wherein said transducer is positioned at the end of the vibratable length of said string.

3. The combination of claim 1 wherein said instrument includes a bridge in contact with a portion of said string defining one end of its vibratable length and wherein said string extends under tension beyond said bridge and is secured at its terminal end to said transducer.

4. A strung musical instrument comprising:

   at least one vibratable string for producing musical tones;

   means for placing said string under axial tension;

   an axially symmetrical piezoelectric transducer disposed at one end of said string with its axis of symmetry aligned with that of said string, said string being secured at its end to said transducer in such manner as to place said transducer under axial compression by the tension in said string;

   said transducer including a pair of spaced apart conductive elements in contact with portions of the surface thereof;

   and electrical conductors in contact with said conductive elements for deriving electrical signals therefrom in response to variations in tension of said string.

5. A strung musical instrument comprising:

   an instrument body;

   an axially symmetrical piezoelectric transducer element having an axially apature therethrough;

   support means bearing against said transducer element at one end of said aperture and supporting said transducer element on said instrument body;

   at least one vibratable string under tension for generating musical tones, said string passing through said aperture and bearing against said transducer element at the opposite end of said aperture, whereby said transducer element is placed under axial compression by the tension in said string;

   an electrically conductive layer on a surface of said transducer element within said aperture;

   a second electrically conductive layer on an external surface of said transducer element surrounding and shielding said first-mentioned conductive layer; and

   electrical conductors in contact with said conductive layers respectively for picking up electrical signals in response to variations in tension of said string when vibrating.

6. A strung musical instrument comprising:

   an instrument body;

   an axially symmetrical piezoelectric transducer element having an axially apature therethrough;

   support means bearing against said transducer element at one end of said aperture and supporting said transducer element on said instrument body;

   at least one vibratable string for generating musical tones, one end of said string extending under tension through said aperture;

   means for securing said one end of said string against said transducer element at the opposite end of said aperture, whereby said transducer element is placed under axial compression by the tension in said string;

   and electrical conductors in contact with spaced-apart portions of said transducer element for receiving electrical signals in response to variations in tension of said string when vibrating.

7. A musical instrument of the string type comprising:

   a substantially rigid body and at least one vibratable string mounted thereon under tension;

   pickup means for converting mechanical string vibrations into electrical oscillations including at least one piezoelectric transducer of hollow generally tubular construction, said transducer having a first conducting surface thereon inside said aperture and a second conducting surface on the outside thereof extending around said transducer in shielding relationship to said first conducting surface;

   support means bearing against one end of said transducer and supporting it in fixed location on said body, said tensioned string extending through said support means and the axial aperture of said transducer and bearing against the opposite end of said transducer, thereby to place said transducer under axial compression; and

   electrical conductors connected to said conducting surfaces to receive electrical signals resulting from variations in tension of said vibratable string.

8. A musical instrument of the string type comprising:

   a substantially rigid body;

   pickup means for converting mechanical string vibrations into electrical oscillations including at least one piezoelectric transducer of hollow generally tubular construction, said transducer having a first conducting surface thereon inside said aperture and a second conducting surface on the outside thereof extending around said transducer in shielding relationship to said first conducting surface;

   support means bearing against one end of said transducer and supporting it in fixed location with respect to said body;

   a bridge on the body of said instrument;

   a vibratable string extending under tension across the body of said instrument into contact with said bridge and beyond said bridge to a terminal end at said transducer, said terminal end extending through the axial aperture of said transducer and bearing against
the opposite end of said transducer thereby placing said transducer under axial compression; and electrical conductors connected to said conducting surfaces to receive electrical potentials resulting from variations in tension of said vibratable string.

9. A musical instrument of the string type comprising:

a substantially rigid body; pickup means for converting mechanical string vibrations into electrical oscillations including at least one piezoelectric transducer of hollow generally tubular construction, said transducer having first and second conducting surfaces in contact with spaced-apart portions thereof; support means bearing against one end of said transducer and supporting it in fixed location with respect to said body; a bridge on the body of said instrument; a vibratable string extending under tension across the body of said instrument into contact with said bridge and beyond said bridge to a terminal end at said transducer, said terminal end extending through the axial aperture of said transducer and bearing against the opposite end of said transducer thereby placing said transducer under axial compression; and electrical conductors connected to said conducting surfaces to receive electrical potentials resulting from variations in tension of said vibratable string.

10. A music instrument comprising:

an instrument body; a pickup for converting mechanical vibrations into electrical oscillations including a hollow axially symmetrical piezoelectric element with an axial aperture extending therethrough mounted on said body, said pickup having a first electrical conductor in contact with a surface of said piezoelectric element within said aperture and a second electrical conductor in contact with an external surface of said element; a vibratable string mounted under tension on said body with one end extending through the aperture in said piezoelectric element; means securing said one end of said string against the opposite end of said element, thereby to place said element under compression; whereby said pickup generates electrical oscillations across said conductors in response to variations in tension of said vibratable string.

11. A musical instrument comprising:

an instrument body; a transducer for converting mechanical vibrations into electrical oscillations including a hollow axially symmetrical piezoelectric element with an axial aperture extending therethrough, said transducer having a first electrical conductor in contact with a surface of said piezoelectric element within said aperture and a second electrical conductor in contact with an external surface of said element; means bearing against said piezoelectric element at one end of said aperture for mounting said transducer on said instrument body; a vibratable string secured at one of its ends to said piezoelectric element at the other end of said aperture and extending axially through said aperture; tuning means at the other end of said string for adjusting the tension on said string thereby placing said piezoelectric element under compression; whereby said transducer generates electrical oscillations across said conductors in response to variations in tension of said vibratable string.

12. A musical instrument comprising:

an instrument body; a transducer for converting mechanical vibrations into electrical oscillations including a hollow axially symmetrical piezoelectric element with an axial aperture extending therethrough, said transducer having first and second electrical conductors in contact with spaced-apart surfaces thereof; means bearing against said piezoelectric element at one end of said aperture for mounting said transducer on said instrument body; a vibratable string secured at one of its ends to said piezoelectric element at the other end of said aperture and extending axially through said aperture; tuning means at the other end of said string for adjusting the tension on said string thereby placing said piezoelectric element under compression; whereby said transducer generates electrical oscillations across said conductors in response to variations in tension of said vibratable string.

13. An electrical pickup for stringed musical instruments comprising:

an axially symmetrical piezoelectric transducer element having an axial aperture therethrough; first and second electrical conductors in contact with spaced-apart surfaces of said transducer element; support means bearing against said transducer element at one end of said aperture for supporting said transducer element on a stringed musical instrument; and means at the opposite end of said axial aperture for securing the terminal end of a vibratable tone-producing string passing axially through said aperture to place said transducer element under axial compression, whereby said electrical pickup generates an electrical signal across said conductors in response to variations in tension produced by such vibratable string.

14. An electrical pickup for stringed musical instruments comprising:

an axially symmetrical piezoelectric transducer element having an axial aperture therethrough; an electrically conductive layer on a surface of said transducer element within said aperture; a second electrically conductive layer on an external surface of said transducer element surrounding and shielding said first-mentioned conductive layer; support means bearing against said transducer element at one end of said aperture for supporting said transducer element on a stringed musical instrument; and means at the opposite end of said axial aperture in said transducer member for receiving the end of a vibratable tone-producing string passing axially through said aperture to place said transducer element under axial compression, whereby said electrical pickup generates an electrical signal across said conductive layers in response to variations in tension produced by such vibratable string.

15. The combination of claim 14 wherein said transducer element is of hollow cylindrical configuration.

16. The combination of claim 14 wherein said transducer element is in the form of a hollow truncated cone.

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