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PICKUPS FOR THE VIBRATIONS OF VIOLIN AND GUITAR STRINGS USING PIEZOELECTRIC BIMORPHIC BENDER ELEMENTS

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Pickups for the Vibrations of Violin and Guitar Strings Using Piezoelectric Bimorphic Bender Elements

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Obtaining a satisfactory pickup for the string vibrations in electronic string instruments (violin family instruments and guitars) is difficult. The pickup should faithfully reproduce the vibrations of the string as an electric voltage. In order to to this the pickup should have the following properties:

1. The pickup should be located close to the string so no intervening structure modifies or filters the vibration.

2. The pickup should be properly oriented with respect to the principal plane of the string motion.

3. The string motion should be closely coupled to the pickup.

4. The pickup should be part of the bridge of the instrument since that is where the vibrations are transmitted to the body in an acoustic instrument.

5. The pickup should allow the string to be mounted in a normal fashion, i.e. to pass over a bridge with a small notch in it so the player will be able to replace the string easily and quickly.

Most commercial pickups are deficient in one or more of these properties and this partly accounts for the big difference in timbre between electronic and acoustic instruments. Electromagnetic pickups used in standard electric guitars are never mounted in the bridge. Piezoelectric pressure sensitive pickups have been mounted in violin bridges, but they are either mounted far from the string or in an orientation in which coupling to the string is marginal or in a way which makes replacing the string awkward.

All commercial piezo-electric pickups with which I am familiar use pressure sensitive elements. It is difficult to properly couple the string vibrations to such an element. If the string passes over a notch in the bridge and the pickup is embedded in the bridge in any orientation, then the coupling will be unsatisfactory because the sound velocity in the bridge is so high that transmitted string vibration will cause the entire pickup to vibrate rather than putting vibratory pressure on the pickup. If the pickup is placed under one foot of the bridge, it is so far from the string that the bridge structure will seriously filter the vibration – usually it will attenuate the important high-frequency components.

One method for properly coupling the string to the pickup is to have the string press against the actual pickup itself in an orientation so that the string vibrations are normal to the pressure-sensitive surface of the pickup. This method does give a good waveform from the pickup. However, in order to have the string press against the pickup, the string must bend slightly where it crosses the pickup so that the tension in the string will press it against the pickup. Arranging the bridge and tailpiece to produce such a bend makes it awkward to mount the string on the instrument and causes some problems in tuning the string.

The essence of the device which I am describing is the use of a bender bimorph piezoelectric element as a pickup instead of a pressure sensitive piezoelectric pickup. The structure of a bimorph is shown in fig 1. It consists of two layers of oppositely-polarized piezo material arranged as shown with a metallic layer between the two piezo layers and metallic electrodes on the outer surfaces of the piezo layers. When a force is applied to bend the pickup as shown, one of the piezo layers will be in compression and the other will be in tension. Since the layers are oppositely polarized, the voltages produced in the piezo layers will add and the sum of voltages will appear across the electrodes. In practice the device is very sensitive, and a small deflection will produce a substantial voltage – a response which typically may be several volts.

The use of the bimorphic pickup in a violin bridge is shown in fig 2. The shape of the bridge is essentially normal except that usual perforations are omitted. These perforations tune that bridge and cause it to couple to the violin body, both functions being unnecessary in an electronic instrument. The violin string passes over a notch in the bridge in a normal manner. Two slits are cut into the bridge on either side of the notch so that the string is actually supported by a narrow beam of material which is free to bend from side to side. The primary direction of string vibration is in a plane perpendicular to the axis of this beam so the string vibration couples well into bending the beam. The piezo bender element is inset into the center of the beam as shown so that it is bent along with the beam by the string motion.

The piezo bender-elements are so sensitive that excellent signals can be obtained from very small elements. Thus it is possible to insert elements into a normal-sized violin bridge and to use this bridge on an acoustic violin. In this way one can achieve an amplified acoustic violin as well as an electronic violin with these elements.

The wave shape of the vibrations of a normal violin string is well known and is a sawtooth function of time. If a pickup produces a faithful sawtooth wave, then it is generally considered to be a good pickup. The wave shape from a piezo bender mounted (in a cello bridge) as shown in fig 2 is shown in fig 3. It is clearly a good sawtooth waveform. The small oscillations superimposed on the sawtooth may be an aberration in the pickup or may be a more complicated mode of the normal string vibration. At the present time, we don't understand the mechanism of the string oscillations well enough to answer this question. However, such small oscillations have always been observed in the motion of violin strings.

One other property of the structure shown in fig 2 is that it decouples the outputs of the individual strings from each other. Since each string has its own pickup and since each string is supported by a separate beam, vibrations from one string produce very little response in the outputs from the pickups on the other strings. Having the strings decoupled is absolutely necessary when an electronic violin is used as a control sensor for a synthesizer since it is often desired to use each string to control a different aspect of the synthesizer sound. Having the strings decoupled is also desirable for an amplified or an electronic violin since it enables the player to individually adjust the loudness and timbre of each string and thus to get an instrument which has a uniform sound on all strings.

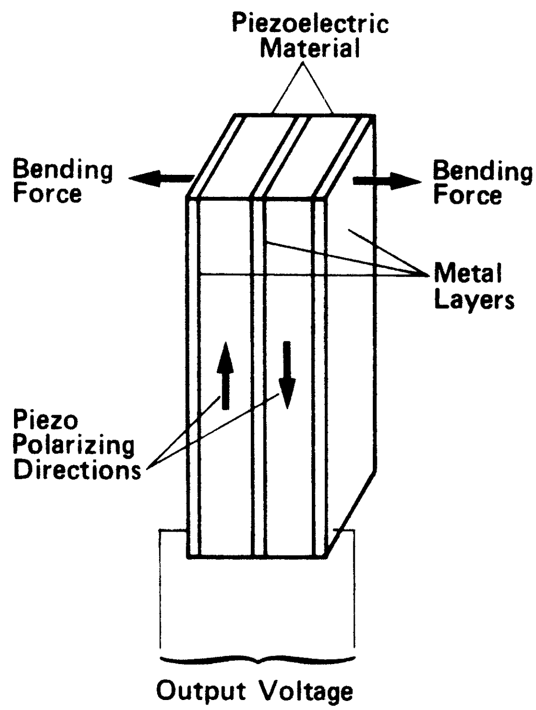

Figure 1. Structure of Bimorph Piezoelectric Bender Sensor

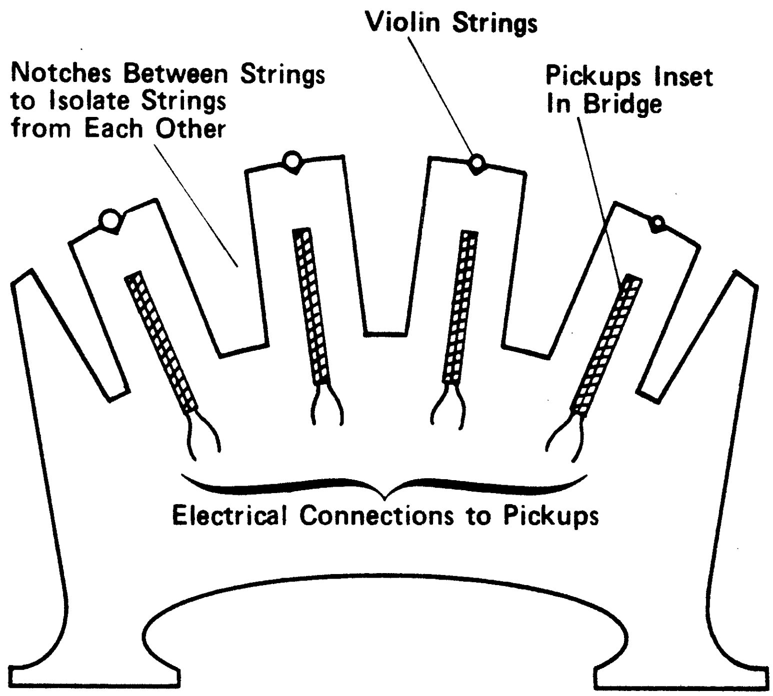

Figure 2. Sketch of Violin Bridge with Bimorphic Pickups

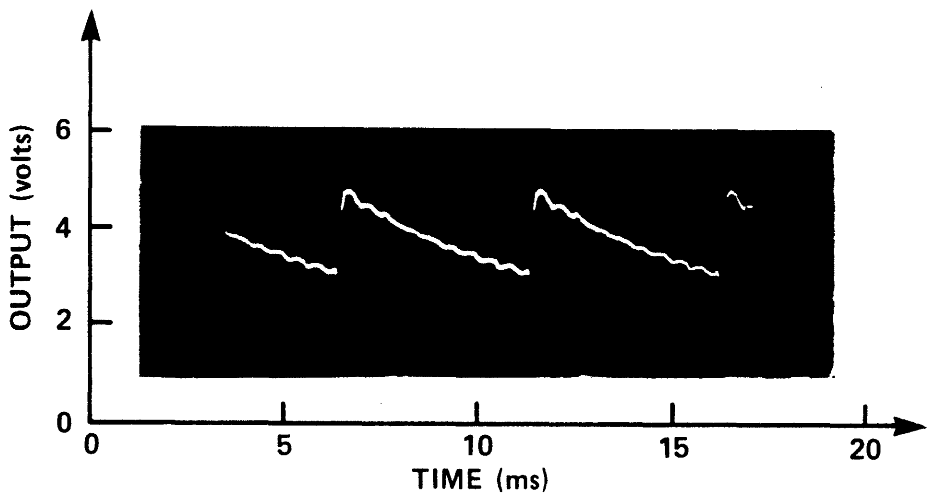

Figure 3. Output of Bender Pickup Mounted in Cello Bridge