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AMPLIFICATION SYSTEM FOR CRYSTAL PICKUPS AND MICROPHONES

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9 Claims. (Cl. 179—1)

This invention relates to an amplification system for crystal pickups and microphones. It is well known that when a piezo-electric crystal such as the Rochelle salt is used as a device for transforming mechanical motion or pressure into electrical energy, the output voltage of the crystal varies with the temperature. This variation in output of the crystal is ordinarily greater at the lower audio-frequencies, the effect being readily noticeable to a person listening to music reproduced from a phonograph record by a piezo-electric pickup or relayed through a piezo-electric microphone. A listener will notice a diminishing of base notes and a falling off in volume level as the temperature at the crystal rises above about 75° F.

One object of the present invention is to provide an amplification system for piezo-electric pickups or microphones in which this objectionable variation in volume is substantially eliminated.

Another object of the invention is generally to improve the amplification of the output of crystal pickups and microphones.

Other objects and features of the invention will be understood from the accompanying drawing and the following description and claims:

The drawing is a diagram of electrical connections showing the invention applied to a crystal pickup.

In the drawing, the reference character 10 indicates a crystal pickup of any well known form by means of which mechanical movement such as the vibration of a stylus following the groove of a phonograph record is transformed into pressure exerted upon a piezo-electric crystal. The variations in pressure cause a correspondingly varying electromotive force to be generated within the crystal and to be impressed upon conductors 11 and 12 connected to appropriate portions of the crystal. A load impedance 13 is connected across the conductors 11 and 12 and passes an electric current caused by the electromotive force generated in the crystal. The conductor 12 is grounded as shown and the conductor 11 is connected to a blocking condenser 14, the opposite terminal of which is connected to the control grid 15 of a thermionic tube 16.

The tube 16 is of a type known commercially as "6L7" or "6L7G" and is classified as a "pentode mixer amplifier." It is provided with a cathode 17 which may be heated by a filament 18 supplied with electric current from any suitable source, not shown. The tube also has the usual anode 19, a suppressor grid 20 connected with

the cathode in the usual manner and three screen grids 21, 22 and 23. The grids 21 and 22 are connected together and are maintained at a substantially uniform potential with respect to the cathode. The grid 23 is placed between the grids 21 and 22 and is supplied with a varying potential. The ratio of amplification or "gain" of the tube may be controlled by varying the potential of the grid 23, an increase of said potential increasing the gain of the tube and a decrease in said potential decreasing said gain.

The necessary potentials for the various elements of the amplification circuits may be provided as shown in the diagram by batteries 24, 25, 26 and 27 or by other suitable arrangement. By way of example, desirable potentials are indicated by numerals in the drawing but need not be strictly followed in securing the benefits of the invention. The control grid 15 is connected through the usual grid leak resistance 28 with a point on the potential supply system at plus 40 volts. The cathode is connected by a conductor 28 with a point maintained at plus 50 volts. The grids 21 and 22 are connected by a conductor 30 with a point maintained at plus 150 volts. The anode 19 is connected through a loading resistance 31 to a point maintained at plus 300 volts and is also connected to a condenser 32, the opposite terminal of which is connected to one of a pair of output terminals 33, the second one of which is grounded. Any suitable apparatus for further amplification may be connected to the output terminals or they may be connected directly to a speaker if the gain of the tube 16 is sufficient to operate a speaker.

The grid 23 is connected by a conductor 34 to a point intermediate between a pair of resistance elements 35 and 36. The opposite terminal of the resistance 36 is grounded and the opposite terminal of the resistance 35 is connected through a resistance 37 to the conductor 30. By this connection, a current constantly flows from the conductor 30 through resistances 37, 35 and 36 to the ground and the potential impressed upon the grid 23 depends upon the voltage drop through the resistance 36. Condensers 38, 39, 40 and 41 are connected as shown and serve the usual purpose of such condensers in amplification circuits.

In the ordinary use of piezo-electric pickups, the load impedance 13 is of the order of 500,000 ohms. With this relatively high impedance, the effect of temperature changes on the output of the piezo-electric crystal is very great at low frequencies and is almost non-existent at the high-

er frequencies. Thus, an increase of temperature reduces the volume of the low frequency sounds and has little or no effect on the volume of the high frequency sounds. According to the present invention, the load impedance 13 is of the order of 25,000 ohms. It has been found after extensive experiments, that this relatively low impedance produces a much more marked temperature effect at the higher frequencies than does the high impedance heretofore in use. There is also some increase in the temperature effect at the low frequencies and of course the low impedance produces a general lowering of the level of the voltage impressed on the condenser 14. However, the net effect of the low impedance is to make the temperature effect on the crystal substantially uniform through the range of useful frequencies and thus to eliminate the frequency discrimination heretofore found in the temperature effects of piezo-electric pickups.

In order to maintain a substantially constant level of output volume irrespective of temperature changes, the resistances 35 and 36 are made of materials having different temperature resistance coefficients and are so placed that they are affected by the same room temperatures which affect the crystal. These coefficients are so chosen that an increase in room temperature increases the resistance of the element 36 in a much greater amount than the resistance of the element 35 may be increased. The increase in room temperature therefore increases the potential impressed on the grid 23 and thus increases the gain of the tube 16 to provide greater amplification. By this means, the amplification of the tube increases as the output of the crystal decreases due to a temperature rise. By a suitable choice of the resistances 35 and 36 and of the materials from which they are made, the increase in gain may be made to compensate for the loss in crystal output and to maintain a uniform volume level with a high degree of accuracy.

The foregoing specification describes the invention in one of its preferred forms. Changes in the details thereof may be made by those skilled in the art without departing from the scope of the invention as defined by the appended claims. For example, the invention is equally applicable to crystal microphones or to any other apparatus in which a pressure responsive crystal is used to transform mechanical motion or pressure into electrical energy. It is also possible to use other temperature responsive means for controlling the gain of the tube than the specific means shown herein, although the latter means in itself constitutes an important feature of the invention.

The invention claimed is:

1. A method of amplifying the output of a piezo-electric crystal by means of a vacuum tube amplifier including the steps of feeding the output of the crystal to a control electrode of the tube, and automatically varying the gain of the tube in response to temperature changes to compensate for changes in output of the crystal caused by such temperature changes.

2. A method of amplifying the output of a piezo-electric crystal by means of a vacuum tube amplifier including the steps of modifying the output of the crystal to compensate for frequency discrimination in the crystal caused by temperature changes, feeding the modified output of said crystal to a control electrode of the tube, and automatically varying the gain of the tube in response to temperature changes to maintain a

substantially constant output level irrespective of the effect of such changes on the output of the crystal.

3. In an amplifier for the output of a piezo-electric crystal, the combination of a vacuum tube having a heated cathode, an anode, a control electrode and an auxiliary electrode adapted to control the gain of the tube by means of varying potentials impressed thereon, a circuit receiving the output of said crystal and connected to the control electrode of the tube, an output circuit connected to said anode, and a circuit connected to said auxiliary electrode and including a temperature responsive element adapted to vary the potential impressed on said auxiliary electrode in response to variations in the temperature affecting said crystal, whereby the gain of the tube may be controlled to compensate automatically for variations in strength of crystal output caused by such temperature variations.

4. In an amplifier for the output of a piezo-electric crystal, the combination of a vacuum tube having a heated cathode, an anode, a control electrode and an auxiliary electrode adapted to control the gain of the tube by means of varying potentials impressed thereon, a circuit receiving the output of said crystal and connected to the control electrode of the tube, said circuit including a loading element of sufficiently low impedance to eliminate frequency discriminations of said crystal caused by variations of the temperature affecting said crystal, an output circuit connected to said anode, and a circuit connected to said auxiliary electrode and including a temperature responsive element adapted to vary the potential impressed on said auxiliary electrode in response to variations in the temperature affecting said crystal, whereby the gain of the tube may be controlled to compensate automatically for variations in strength of crystal output caused by such temperature variations.

5. In an amplifier for the output of a piezo-electric crystal, the combination of a vacuum tube having a heated cathode, an anode, a control electrode and an auxiliary electrode so placed with respect to the elements of the tube as to increase the gain of the tube when the potential impressed thereon is increased and to decrease the same when said potential is decreased, a circuit receiving the output of said crystal and connected to the control electrode of the tube, an output circuit connected to said anode, and a circuit connected to said auxiliary electrode and including a temperature responsive element adapted to increase the potential impressed on said auxiliary electrode in response to an increase in the temperature affecting said crystal and to decrease said potential in response to a decrease in said temperature, whereby the gain of the tube may be controlled to compensate automatically for variations in strength of crystal output caused by such temperature variations.

6. In an amplifier for the output of a piezo-electric crystal, the combination of a vacuum tube having a heated cathode, an anode, a control electrode and an auxiliary electrode adapted to control the gain of the tube by means of varying potentials impressed thereon, a circuit receiving the output of said crystal and connected to the control electrode of the tube, an output circuit connected to said anode, an auxiliary circuit including a pair of resistance elements connected in series and having different temperature resistance coefficients, said circuit also including means for impressing a substantially constant

5 voltage across said resistance elements and said
elements being so placed as to be affected by the
temperature affecting said crystal, and a con-
nection between said auxiliary electrode and a
point in said circuit intermediate of said resist-
10 ance elements, the temperature resistance coeffi-
cients of said elements being so chosen as to pro-
duce, in response to temperature variations,
potential changes on said auxiliary electrode
sufficient to regulate the gain of the tube to
substantially compensate for the effect of said
temperature variations on the output of the
crystal.

15 7. In an amplifier for the output of a piezo-
electric crystal, the combination of a vacuum
tube amplifier, an input circuit therefor receiving
the output of said crystal, and temperature con-
trolled means responsive to the temperature af-
fecting said crystal for automatically varying the
20 ratio of amplification of said amplifier to com-
pensate for changes in the output strength of
the crystal caused by variations in said tem-
perature.

8. In an amplifier for the output of a piezo-

electric crystal, the combination of a load circuit
connected to said crystal and having a sufficiently
low impedance to insure substantially uniform
temperature effects over the range of useful fre-
quencies, a vacuum tube amplifier having an in-
5 put circuit connected to said load circuit, and
temperature controlled means responsive to the
temperature affecting said crystal for automati-
cally varying the ratio of amplification of said
amplifier to compensate for changes in the output
10 strength of the crystal caused by variations in
said temperature.

9. In an amplifier for the output of a piezo-
electric crystal, the combination of a load circuit
connected to said crystal and having an imped-
15 ance of the order of 25,000 ohms, a vacuum tube
amplifier having an input circuit connected to
said load circuit, and temperature controlled
means responsive to the temperature affecting
said crystal for automatically varying the ratio
20 of amplification of said amplifier to compensate
for changes in the output strength of the crystal
caused by variations in said temperature.

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