May 8, 1951 F. D. MERRILL, JR 2,551,807

ELECTRONIC MUSICAL INSTRUMENT

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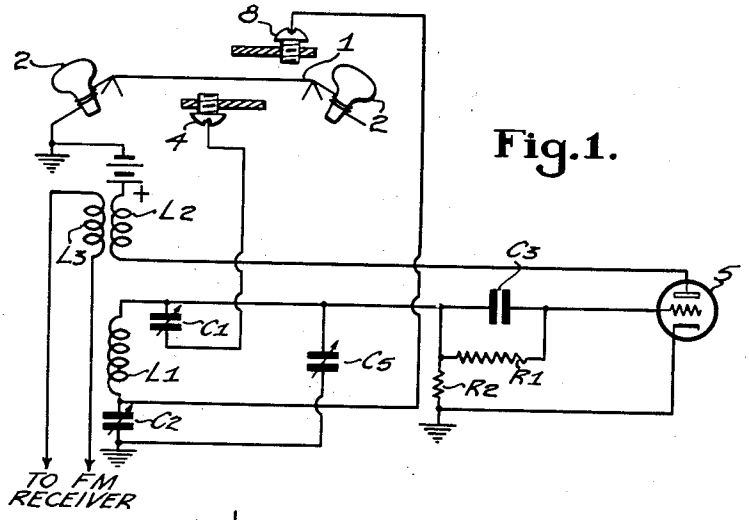



Fig. 1.

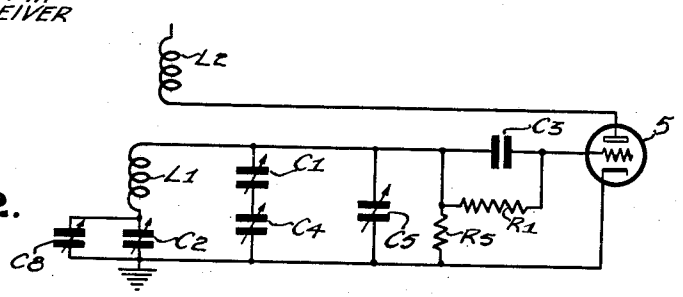



Fig. 2.

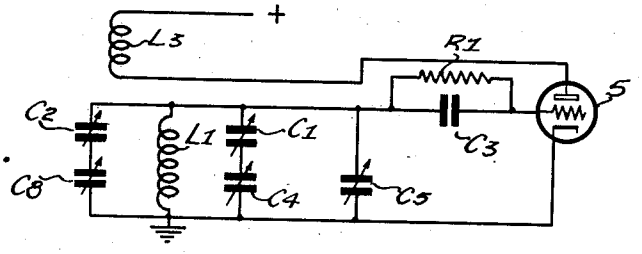
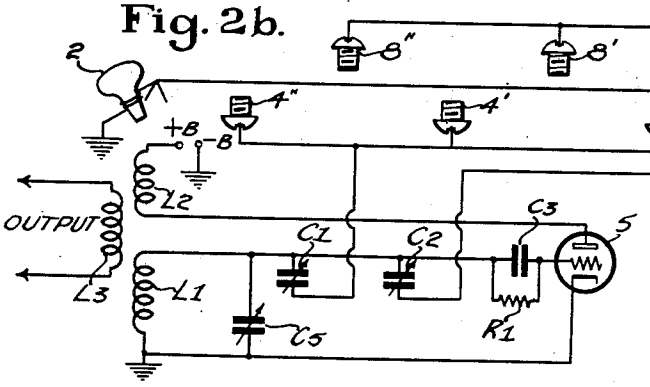



Fig. 2a.

Fig. 2b.




INVENTOR.
FREDERIC D. MERRILL JR.
BY H. S. Grover
ATTORNEY

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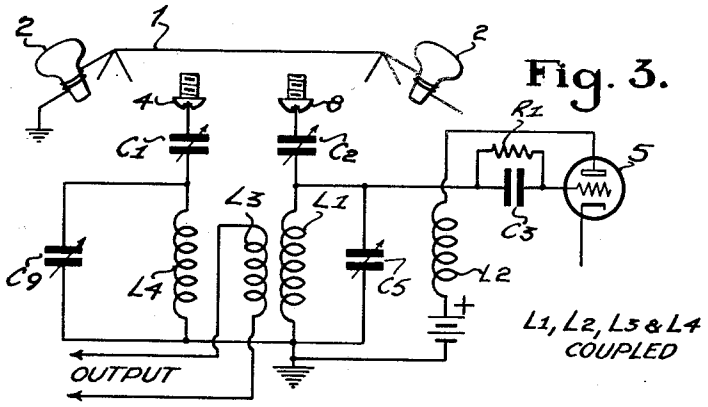



Fig. 3.

Fig. 3a.

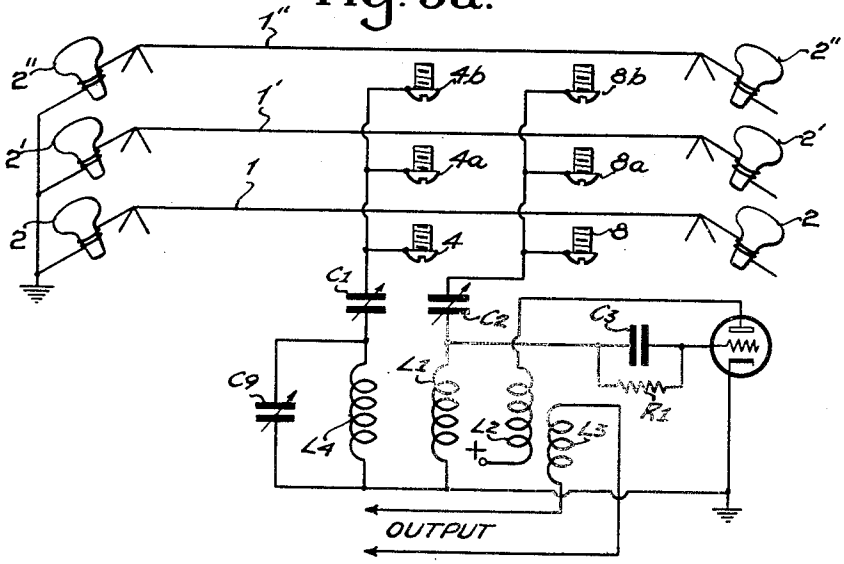
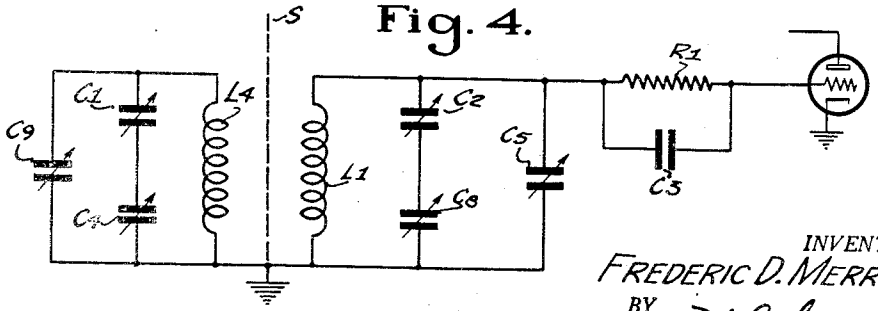



Fig. 4.




INVENTOR.
FREDERIC D. MERRILL JR.
BY H. S. Brown
ATTORNEY

May 8, 1951 F. D. MERRILL, JR 2,551,807

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Fig. 5.

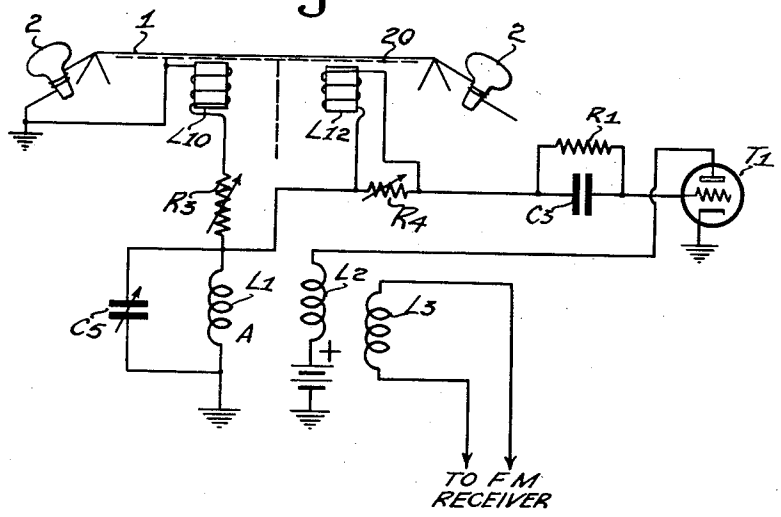



Fig. 5b.

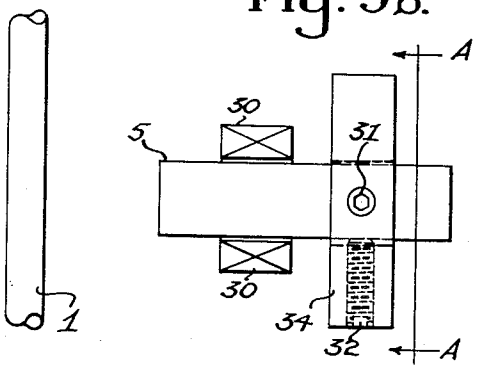
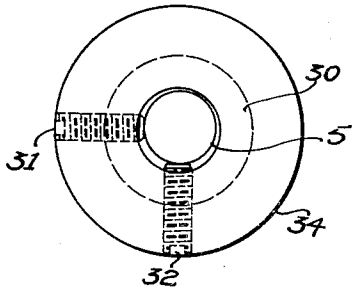



Fig. 5a.




SECTION AA

INVENTOR.
FREDERIC D. MERRILL JR.
BY H. S. Brower
ATTORNEY

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2,551,807

# UNITED STATES PATENT OFFICE

2,551,807

## ELECTRONIC MUSICAL INSTRUMENT

Frederic D. Merrill, Jr., Orange, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 7, 1944, Serial No. 562,347

4 Claims. (Cl. 250—36)

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This application relates to electronic musical instruments. In this application I disclose an improved method and means for obtaining a greater range of timbre in an electronic musical instrument, using mechanical vibrators such as strings, reeds, rods, plates, bars, membranes, etc. Another application is to compare the nature of the vibrator motion at different portions of the vibrator.

A primary object of my invention is extension of the timbre range of musical instruments of the electronic type.

An additional object of my invention and one resulting from the attainment of the primary object is comparison of vibratory motion at different points on the vibrator.

An advantage of obtaining a greater range or variety of timbre is to increase the tone expressiveness of the instrument and to simulate to as great a degree as possible orchestral timbres. For example, in a piano the obtaining of a strident timbre presents difficulties which are only fully solved by means of my invention. On the other hand by my invention more or less strident timbre may be obtained thus extending the range of timbre obtainable. Other examples will occur to those versed in the electronic musical art.

For the sake of brevity and clearness and to simplify the description, reference will be made hereinafter to electronic instruments of the string type. My invention, however, is applicable to any vibrating body such as piano strings, reeds, etc.

The broad concept is as follows. The relative amplitude of each harmonic motion of the string varies along the string length. For example, the fundamental mode of vibration has a maximum amplitude at a point half-way along the string length. Also along the string length there is a steady progression of points of maximum vibration for a given harmonic and points of minimum amplitude of motion for the same harmonic. The characteristic vibration at any point along the string length may be translated into corresponding variations of electric current flow by means of suitable pickup devices spatially separated from the strings. These may be based on magnetic, capacitative, or other methods. If now such pickups are arranged in opposing relationship as far as the generated voltage is concerned, then a new group of timbres may be obtained giving a wider range of tone quality than that from any single pickup located at any one point along the string length. The use of reactive

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pickups in bucking arrangements for frequency modulation of oscillatory energy is novel and useful. I have disclosed various means for obtaining bucking pickup with frequency modulation systems. The like components from the outputs of two differently effective pickups are cancelled out, leaving a strikingly different timbre from that of the separate outputs. The pickups may be differentially associated with the vibrating element or may be located in similar relation with respect to the element and their effects used differentially.

In describing my invention in detail reference will be made to the attached drawings wherein

Fig. 1 illustrates by circuit diagram the essential features of my improved electronic pickup and modifying means. As illustrated this means includes an oscillation generator, a frequency determining circuit therefor, a vibratory element and a reactance, comprised in part thereby, variable by motion thereof, for tuning the oscillation generator to various frequencies.

Fig. 2 is a basic diagram illustrating the manner in which the frequency control of the arrangement of Fig. 1 is accomplished.

Fig. 2*a* is a modification of the arrangement of Fig. 1.

Fig. 2*b* is a modification of the arrangement of Fig. 2*a*.

Figs. 3, 4, and 5 each illustrate modified embodiments of my system as illustrated in the prior figures. In Fig. 3 the pickup elements are arranged on the same side of the vibratory element, whereas in Fig. 1 they are arranged on opposite sides.

Fig. 4 is a basic diagram of the arrangement of Fig. 3.

In Fig. 5 magnetic pickup means is used, whereas capacitive pickup means are used in the prior figures.

Figs. 5*a* and 5*b* illustrate details of means for adjusting the pickup elements of Fig. 5 relative to the strings of an instrument such as a piano.

Fig. 3*a* illustrates a modification of the arrangement of Fig. 3.

Referring to Fig. 1, a metal string 1 is stretched between two bridges by means of the tuning pins 2. The capacity variations between a metal string and spatially separated electrodes 8 and 4 are used to frequency modulate a super-audible generated voltage. The electrodes 4 and 8 may be machine screws mounted in supports (not shown) for adjustment toward and from the string 1. For electrostatic shielding and con-

venience of construction the strings (of which but one is shown) are grounded. The two capacity pickups may be at different positions along the string but on opposite sides of the string. There is capacity between the string and each metal adjustably positioned machine screw 4, 8. The capacity varies as the string vibrates. Feedback from L2 in plate circuit of tube 5 to the grid coil L1 causes the tube 5 to oscillate. This oscillation is assisted by the grid leak condenser R1, C3, as well as the necessary D. C. return path from the grid of the tube through R2. Fig. 2 shows by simplified connections the capacity varying part of Fig. 1. The top plate of C4 represents the pickup electrode 4. The top plate of C8 represents the pickup electrode 8. The variable condensers C1 and C2 determine the magnitude of the effect of each pickup on the resonant frequency of the oscillating circuit. As the string 1 moves towards pickup 4, the capacity C4 increases, tending to lower the resonant frequency. The string 1, however, is simultaneously receding from pickup 8 so that C8 diminishes, tending to raise the generated frequency. The instantaneous capacity in the resonant circuit is therefore the difference between C8 and C4. The like capacity changes therefore neutralize one another, leaving only the dissimilar capacity variations. The amount of bucking is of course predicated upon the adjustments of C2 and C1. C2 and C1 also determine the maximum frequency swing of the carrier frequency. L2 merely picks up the frequency modulated voltage and supplies it to a utilization circuit such as for example an F. M. receiver. C5 adjusts the overall quiescent frequency of the oscillator.

In Fig. 2*a* I have shown an alternative method by means of which the resistance R2, indicated as R5 in Fig. 2, is eliminated. In this arrangement as in the prior embodiment C4 and C8 are the variables and inspection of this figure will show that when C4 is increased it will tend to lower the frequency of the operation of the generator, since it is in shunt to the tank circuit including L1. At the same time the reactance of C8 decreases and since this condenser is in shunt to the tank circuit it will have a tendency to increase the frequency of operation thereof so that the like variable components oppose and cancel, leaving the resultant capacitive effect representing primarily harmonic modes of vibration of the string which are unlike at the two pickup points.

While in Figs. 1, 2, and 2*a* I have shown a single pair of pickup elements 4 and 8 adjacent the vibratory element, it will be understood that additional pairs 4', 8' and 4'' and 8'' may be added and connected in parallel with the reactive pickups 4 and 8, as illustrated in Fig. 2*b*. The number of pickups is of course limited by the total fixed reactance placed on the tank circuit.

Moreover, it will be understood that in these embodiments and in the ones which follow, pickup elements associated with a large number of strings such as in a piano may be associated with one oscillator or there may be an oscillator for groups of strings, for example, for each octave.

In some cases it is advantageous to have the pickups on opposite sides of the strings as in Fig. 1, because they can be placed nearly opposite to each other to give maximum differential effect to make use of the higher harmonics. However, if the structure of the instrument to which my invention is applied is such that application of the pickups on opposite sides of the string is difficult mechanically, the pickup electrodes may all be placed on the same side of the string. This modification may be applied to the arrangements of Figures 1, 2, and 2*a* provided certain changes are made. The changes necessary will be clear to one who understands the arrangement shown in Fig. 3. In the arrangement of Fig. 3 pickups on the same side of the string are used. A piano is an example of an instrument where it may be desirable to have pickups on the same side of the vibratory element. In this instrument location of the pickups on opposite sides of the string is not convenient mechanically and certainly would be more expensive than an arrangement where the pickups are on the same side of the string. Fig. 3 shows a method for avoiding this situation. The associated varying capacity elements are drawn more clearly in Fig. 4. The feature of this circuit is the L4, C1, pickup capacity from the pickup 4 to ground. This portion of the circuit acts something like a short circuiting inductance to L1, to which inductance L4 is coupled and thus will affect the oscillator frequency. The coupling between L1 and L4 should be primarily magnetic, not electrostatic, and electrostatic shielding S between the two coils may sometimes be necessary to insure all magnetic coupling. An explanation of the functioning of the circuit is as follows. Suppose the metal string 1 approaches the two pickups 4 and 8. C4 and C8 represent the capacity between the string and electrodes 4 and 8 respectively. If C4, the capacity of string to pickup electrode, increases, this diminishes the impedance across L4 and tends to decrease the inductance of the L1 circuit and thus raises the oscillator frequency. However, as the string is approaching both pickups simultaneously, C8 also increases, and tends to lower the oscillator frequency. The difference between the relative magnitudes of these two effects will determine the actual oscillator frequency. Similar capacity changes cancel out, leaving only the unlike portions. C1, C2, C9 determine the individual effects of each pickup capacity change on the oscillator frequency. C5 gives an overall control of the oscillator frequency.

Fig. 5 shows a method for obtaining magnetic pickup bucking action, again employing frequency modulation as the energy source being modulated. In this case the vibrating string 1 should be of iron or steel. The electrostatic shielding is shown at 20 by the dash line. The magnetic pickup coils L10 and L12 are individually adjustable in separation from the string just as in the case of the other figures. The cores may be air, soft iron, or a permanent magnet. L1, L2 here as in the prior figure constitutes the oscillating circuit whose frequency will be varied in accordance with the variations of inductance of L10 and L12. The inductance of L10 and L12 will vary because the approach of the steel string will change the flux linkages set up by the winding (the oscillator current flows in the magnetic pick-up coil). As the string 1 nears the two pickups, both L10 and L12 increase in inductance. The inductance of L12 is additive to (in series with) that of L1, so the oscillator frequency should tend to diminish. L10 is in a circuit parallel with L1 so the total inductance should diminish and therefore the oscillator frequency rise. These are two opposing effects so like vibration components of the string tend to be cancelled out, leaving only the unlike components. R3 and R4 are rheostats to

vary the effect of L10 and L12 respectively on the oscillator frequency. C5 again adjusts the overall oscillator frequency to any desired value.

Adjustment of the pickup elements of Fig. 5 with respect to the string may be accomplished in various ways. For example, as illustrated in Figs. 5*a* and 5*b* the magnetic pickup coil winding 30 (L10 and L12 Fig. 5) may be associated with a magnetic pole 5 adjustably mounted in a support 34 for movement toward and away from the string 1. Set screws 31 and 32 having slotted heads may be passed through the support 34 and bear on the pole piece 5 to retain the same at the desired distance from the string 1. In some cases it is preferable that the set screws 31 and 32 have hexagon heads (recessed) so that they may be conveniently turned by a hexagon wrench passed through the strings and pivoted in a plane between strings.

In all six circuits described hereinbefore and in Fig. 3*a* described hereinafter there is assumed to be mutual induction between all coils. The oscillator frequency should be above the range of hearing. The effect of minute capacity or inductance changes on the frequency of an oscillating circuit will in general increase with the frequency. This may recommend the use of a high oscillator frequency. Also spurious mechanical vibration (of electrical circuit parts) should be eliminated to prevent introduction of spurious signals.

A separate oscillator for each vibrator is not necessary for the pickups or groups thereof may all be placed in parallel with each other. This is illustrated in Fig. 3*a* wherein additional strings 1′ and 1″ have associated therewith pickups 4*a* and 8*a* and 4*b* and 8*b*. This arrangement otherwise may be as illustrated in any of the prior figures. As illustrated, Fig. 3*a* is basically as illustrated in Fig. 3 and operates in the same manner in which the arrangement of Fig. 3 operates.

In my improved method and means, then, the effects of the fundamental and lower harmonics cancel to a greater extent than the higher harmonics, the nodes and antinodes of which are closer together. This then stresses and enhances the higher harmonics. If the pickups are spaced farther apart, stressing of the higher harmonics may be reduced by selection of the pickup points. As the separation between the points of pickup is increased the difference between the opposing effects at the fundamental mode of operation is increased. The higher the order of the harmonic the shorter the distance between the nodes and antinodes, therefore bringing the pickups toward each other causes a more complete cancellation of the fundamentals, leaving predominantly variations of the higher harmonic modes of operation. Particularly is this so when the pickups are near the ends of the vibrating string.

What is claimed is:

1. In an electronic instrument, in combination, an oscillation generator comprising an electron discharge tube having electrodes coupled in a circuit including an inductance between two of the tube electrodes, a second inductance coupled to said first inductance, a conductive vibratory element having one terminal connected to one terminal of each of said inductances, a pair of pickups adjacent said element each to provide a varying reactance as said element vibrates, a connection to one pickup for putting one of the said reactances in shunt to one of said inductances, a connection to the other pickup for putting the other of said reactances in shunt to the other of said inductances, and an output circuit coupled to said generator.

2. In an oscillation generator, an electron discharge device having electrodes regeneratively coupled in an oscillation generating circuit including a reactance, a conductive vibratory element having one terminal coupled to said reactance, a pair of pick up devices spaced along one side of said vibratory element to provide reactance variations of different magnitudes as said element vibrates, and couplings between said pick up devices and said reactance for adding said reactance variations differentially to the reactance of said circuit.

3. In an oscillation generator, an electron discharge device having electrodes regeneratively coupled in an oscillation generating circuit including an inductance, a conductive vibratory element having one terminal coupled to said inductance, a pair of pick up devices spaced along one side of said vibratory element to provide capacity variations of different magnitudes as said element vibrates, and couplings between said pick up devices and said inductance for adding said capacity variations to the inductance of said circuit in opposed sense.

4. In an oscillation generator, an electron discharge device having electrodes regeneratively coupled in an oscillation generating circuit including an inductance connected between two of the electrodes of said device, a conductive vibratory element having one terminal coupled to said inductance, a pair of pickup devices spaced along one side of said vibratory element to provide inductance variations of different magnitudes as said element vibrates, one of said pickup devices comprising a magnet having a core in inductive relation to said element and having a winding coupled in series with said inductance and the other of said pickup devices comprising a magnet having a core in inductive relation to said element and having a winding coupled in shunt to said inductance, whereby said inductance variations are added differentially to the inductance of said circuit, and an output circuit coupled to said oscillation generating circuit.

FREDERIC D. MERRILL, JR.

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