Feb. 22, 1944. J. M. HANERT 2,342,338

ELECTRICAL MUSICAL INSTRUMENT

Filed June 20, 1942

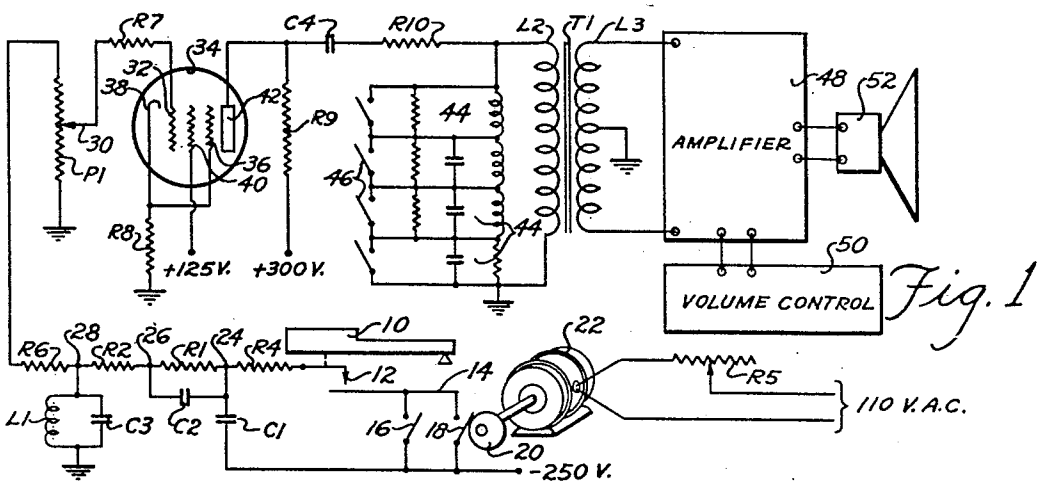

Fig. 1

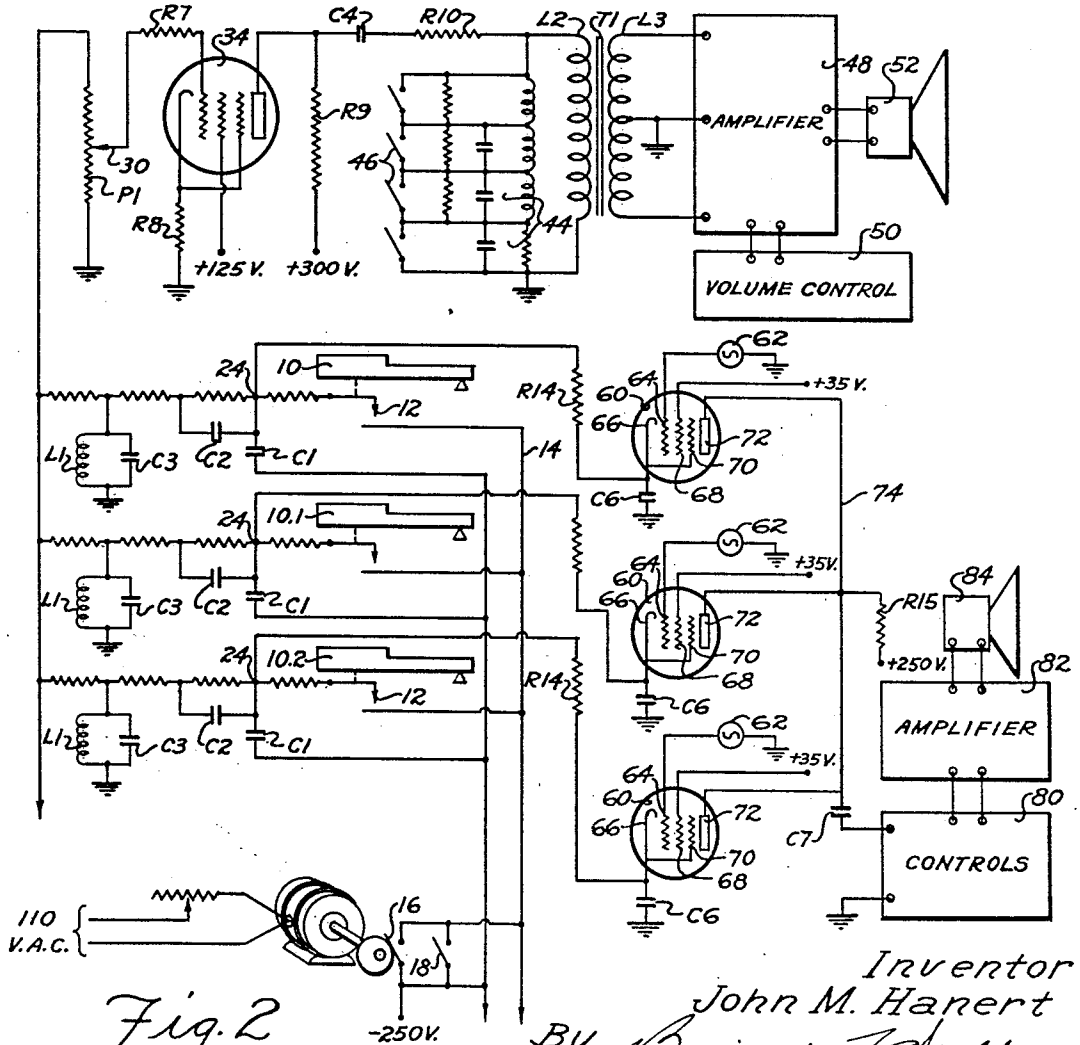

Fig. 2

Inventor
John M. Hanert
By Benjamin F. Nupper
Atty.

Patented Feb. 22, 1944

2,342,338

UNITED STATES PATENT OFFICE

2,342,338

ELECTRICAL MUSICAL INSTRUMENT

John M. Hanert, Wilmette, Ill., assignor to Hammond Instrument Company, Chicago, Ill., a corporation of Delaware

Application June 20, 1942, Serial No. 447,771

16 Claims. (Cl. 84—1.20)

My invention relates generally to electrical musical instruments, and more particularly to improved means for obtaining percussive effects.

It is an object of my invention to provide an improved electrical musical instrument having means for producing sounds similar to those produced by the marimba, by the xylophone, by Chinese blocks, and by plucking violin and bass viol strings.

A further object is to provide an improved electrical musical instrument having means for producing an initial percussive sound of recognizable pitch together with or followed by a sustained tone of definite pitch.

A further object is to provide an improved musical instrument for producing iterative percussive sounds of recognizable pitch.

Other objects will appear from the following description, reference being had to the accompanying drawing in which:

Figure 1 is a wiring diagram of a percussive sound producing instrument; and

Figure 2 is a wiring diagram of a musical instrument for producing polyphonic percussive sounds combined with sustained tones.

General description

The percussion sound signal generator comprises generally a transient producing means in the form of a normally charged condenser which, upon depression of a key, is discharged rapidly at a controlled rate. The electrical signal pulses generated upon discharge of this condenser consist of an infinite number of frequencies, all of which are in phase at the instant that the condenser discharge starts. The discharge of the normally charged condenser may be controlled by a manually operated switch or by a periodically operated switch under manual control.

The signal pulse generated upon the discharge of the normally charged condenser is transmitted through appropriate filter meshes for attenuating undesired frequencies, leaving in the transmitted signal a preponderance of a narrow band of audio frequencies of recognizable pitch. By non-linear distortion apparatus, the pitch of this sound signal may be made more definite through the introduction of harmonics. For added musical interest a periodically closed or iterative switch may be rendered effective to cause repetition of the generating process during the interval that a manually closed switch is held closed.

The output of the harmonic distortion apparatus is selectively modified by tone controls, amplified with controllable gain, and translated into sound.

The signal generating apparatus of Figure 1

Referring to Figure 1, the electrical signal generator comprises a condenser C1, one side of which is connected to a terminal of a suitable power supply indicated as a terminal —250 v., the other side of the condenser C1 being connected to ground through series resistors R1 and R2 and an inductance L1. The condenser C1 is thus normally maintained charged at a potential difference of 250 volts.

The condenser C1 may be discharged at the will of the player by operation of a key 10 which, upon being depressed, closes a switch 12, thus connecting the normally grounded side of the condenser C1 to a conductor 14 through a resistor R4. The conductor 14 is adapted to be connected to the —250 v. terminal either through a manually closed switch 16 or through an iterative switch 18. The switch 18 is adapted to be closed periodically, approximately six times per second, by a cam 20 driven by a variable speed motor 22, the latter having its speed controlled by a suitable rheostat R5. It will thus be seen that while the key 10 is held depressed, the switch 16 being open, the iterative switch 18 will have the same effect as rapidly and repeatedly depressing the key 10 when the switch 16 is closed, namely, repeatedly discharging the condenser C1 through the resistance R4.

By making the resistance R4 of relatively high value, the condenser C1 will discharge at a relatively low rate, and a harmonic analysis of the pulse generated will show it to be relatively free of high frequencies. On the other hand, if the value of resistance R4 were relatively low, the wave form of the pulse generated would be very abrupt and contain a preponderance of the higher frequencies.

The electrical pulse generated upon the discharge of condenser C1 is modified as to its frequency spectrum by filtering meshes. As previously indicated, the mesh comprising the condenser C1 and resistance R4 attenuates the high frequencies. A condenser C2 is connected between junction points 24 and 26, and thus in parallel with resistor R1, and forms with the resistor R2 a means for attenuating the lower frequencies. The inductance L1 has a condenser C3 connected in parallel therewith between a junction point 28 and ground, and this mesh is designed to be resonant at the desired audio frequency.

The junction point 28 is connected through a resistor R6 to one terminal of the potentiometer P1, the other terminal of which is grounded. The sliding contactor 30 of the potentiometer P1 is connected through a series grid resistor R7 to the grid 32 of a sharp cutoff pentode 34 which may be of the 6J7G type. This pentode may have its suppressor grid 36 directly connected to its cathode 38, and the latter connected to ground through a biasing resistor R8. The screen grid 40 of the tube 34 may be maintained at a suitable operating potential by connection to a terminal of the power supply indicated at +125 v. while the plate 42 of this tube is connected through a load resistor R9 to a suitable source of plate potential, indicated as a terminal +300 v. of the power supply system.

The output of the pentode 34 is coupled to the primary winding L2 of a coupling transformer T1 through a blocking condenser C4 and decoupling resistor R10. The primary winding L2 is adapted to be selectively connected in parallel with one or more of a plurality of suitable tone control meshes 44 upon opening one or more of a plurality of switches 46.

The secondary L3 of the transformer T1 is connected to a push-pull amplifier 48 which may be provided with a suitable volume control means 50, the output of the amplifier being coupled to a speaker 52.

Assuming that the mesh L1—C3 is resonant at a frequency of 440 C. P. S., which is the predominant frequency of the sound to be produced, the resistance R4 should be of such value relative to that of the condenser C1 that frequencies above 440 C. P. S. will be appreciably attenuated. As a practical matter it is desirable that excessive sparking shall not occur upon the closure of switch 12 or switch 18. The value of C1 is determined in view of this consideration. Practical considerations also indicate that the condenser C1 should be made as large as feasible since it is desirable to produce a high amplitude signal pulse. The value of R4 is then such as to produce the desired frequency response characteristics of this mesh. For example, the condenser C1 may have a value of .05 mfd., while the resistance R4 is 200 ohms, which is sufficient resistance to suppress undesirable sparking.

The pulse thus generated at the junction point 24 is transmitted through the current limiting mesh consisting of the series condenser C2 and series resistance R2. The values of these latter elements are so chosen as effectively to attenuate frequencies lower than those desired to be generated, that is, for the note A–440, all frequencies lower than 440 C. P. S. For this frequency the condenser C2 may have a value of .05 mfd. and the resistance of R2 may be 30,000 ohms.

Thus, the pulse signal appearing at the junction point 28 has all of the audio frequencies, except those within the 440 C. P. S. range, greatly attenuated. If this electrical signal at the junction point 28 were translated into sound, it would scarcely be recognizable as of a pitch in the musical scale, and would thus not be suitable for use in the production of music except as a primarily percussive noise.

The parallel tuned mesh consisting of inductance L1 and condenser C3 is provided pronouncedly to attenuate all frequencies in the signal pulse at the junction 28, except the 440 C. P. S. frequency and frequencies very close to 440 C. P. S. The "Q" (X/R ratio), namely, the ratio of the reactance to the resistance of the inductance L1 is made as high as compatible with considerations of cost. The impedance of this L1—C3 mesh is designed to be low relative to the resistance of R2 and resistor R6. Thus, the pulse signal impressed upon the grid 22 of the tube 34 will contain a preponderance of frequencies very close to 440 C. P. S.

Depending upon the losses in the L1—C3 mesh and the losses in the input and output circuits of this mesh, the initial excitation of this mesh will cause the desired frequency signal to be impressed upon the grid 32 for an appreciable length of time at a rapidly decaying amplitude. The damping rate will be determined mainly by the "Q" of the L1—C3 mesh.

The pentode 34, being of the sharp cutoff type, will effectively distort the input signal, and assuming that the input signal is approximately a sine wave, the output signal of the tube 34 will have a square boxlike wave form. Such wave form consists of the fundamental with a long series of the higher harmonics at substantial amplitudes, so that the tone has a more readily recognizable pitch and the tone controls 44 may be effective appreciably to modify the quality of the tone signal by selectively attenuating the various partial frequencies.

The series grid resistor R7 limits the grid current. The value of the resistor R8 is such that the average plate current is relatively constant for all amplitudes of the input signal. Thus, no serious transients due to change in plate current are introduced by the sudden application of the signal to the control grid, and the output wave tends to be of square shape, particularly when the grid signal is of high amplitude. Furthermore, the highly damped input wave produces an output wave which is of relatively constant amplitude for a brief interval and then decays rapidly.

The over-all result attained by the use of the non-linear pentode 34 is to increase the pitch discernability of the signal and to increase the apparent duration of the tone. The sound produced thus resembles that obtained from a plucked string or xylophone. Without the distorting effect of the pentode 34 the sound is more like that of a Chinese block or marimba, depending upon the constants of the filter meshes. This latter non-distorting result is obtained by setting the potentiometer slide contact 30 close to the grounded end of the potentiometer resistance. Under these conditions the pentode 34 will amplify the input signal in a substantially linear manner.

The tone quality of the output signal of the pentode 34 is modifiable by the tone quality control meshes 44 by which the sound ultimately produced may be changed to resemble xylophone or marimba tones by respectively attenuating the low or the high frequencies.

It will be noted that no blocking condenser is required for the grid 32. This is because the resistance of the inductance element L1 is so low relative to the resistance of R1 (e. g. 10 ohms compared to 500,000 ohms), with the result that the steady voltage across the potentiometer P1 is negligible.

The transient usually present upon releasing the playing key is made negligible by making the charging resistor R1 very high, for example, 500,000 ohms. Resistor R2 is also part of the charging resistance but is of relatively low value

and may be neglected in this respect. Thus, the charging rate is of the order of 1/2600 of the discharging rate, the discharge being through resistor R4 which may have a value of only 200 ohms. The net result is that the musician need not be concerned about how long the key is held down, since no sound is heard when the key is released. The value of resistor R1 should not be too high, for if it were, the condenser C1 would not be charged up in time for a second note to be played, such as a repeated note. The 500,000 ohm value for R1 is chosen on the basis of a maximum iterative speed of approximately 8 per second.

An iteration effect may be produced by opening switch 16. This makes switch 18 effective alternately to connect and disconnect the —250 volt supply and the conductor 14 as long as the key 10 is held depressed.

The invention as shown in Figure 1 and described above is of the simplest form and in actual practice may be embodied in a variety of different types of instruments for obtaining special results. The invention may be embodied in a separate instrument for use in an orchestra or may be combined with other electrical musical instruments such as electric organs and the like to produce special percussive effects. One such embodiment is illustrated in Figure 2 wherein the elements previously described bear corresponding reference characters and will not be again described.

Instead of having but a single key 10 for controlling the operation of the instrument there are provided a plurality of additional keys 10.1, 10.2 which are representative of a large number of similar keys of any desired range, such as of three or four octaves. For example, the filtering meshes associated with the key 10 may be chosen to produce a tone signal for the note A of 440 C. P. S., while the filtering meshes associated with the key 10.1 may be selected to produce a tone A# of 466.16 C. P. S., and the meshes associated with the key 10.2 may be selected to produce the tone B of 493.88 C. P. S. In designing the tuning meshes, particularly the resonant mesh L1—C3, the tuning may conveniently be effected by utilizing this mesh in the feedback circuit of an oscillator, so that the note may be made to sound continuously and the accurate adjustment of the inductance value facilitated.

In Figure 2 the depression of a key is adapted not only to produce any one of a plurality of percussive tones of the desired pitch, but the operation of the key also controls the sounding of a sustained tone for the duration of the time that the key is held depressed. This means comprises a plurality of control tubes in the form of pentodes 60. Suitable generators 62 of frequencies corresponding to those determined by their respective filtering meshes L1—C3, in the example given 440, 466.16 and 493.88 C. P. S., are impressed upon the grids 64 of the pentodes. Instead of having the resonant frequencies of the L1—C3 meshes be the same as those of the generators 62, these meshes may be made to have frequencies which are harmonics of those of the generators 62. In the example given, if the generator 62 associated with key 10 has a frequency of 440 C. P. S., the associated mesh L1—C3 may be made to resonate at 1320 C. P. S., 880 C. P. S., or at any other desired harmonic frequency.

The cathode 66 of each of the pentodes 60 is connected to ground through a relatively large condenser C6 and is connected to the terminal 24 through a relatively high value resistor R14. The screen grid 68 is connected to a suitable operating potential such as +35 v., while the suppressor grid 70 of each of these tubes is connected to the cathode 66. The plates 72 of a plurality, or all, of a group of the tubes 64 are connected to a common conductor 74 which is connected to a suitable source of plate current indicated as +250 v. of the power supply system through a load resistor R15. The conductor 74 is connected through a blocking condenser C7 with manually operable controls indicated diagrammatically by the block 80. The signal, as modified by the controls, is amplified by an amplifier 82 and translated into sound by the speaker 84. The generator 62, the control tube 60, and the output circuits therefor may be of the type used in the "Novachord" or as disclosed in the patents of Laurens Hammond, Nos. 2,126,464 and 2,126,682.

From the foregoing it will be apparent that when any one of the keys 10, 10.1, 10.2, etc., is depressed electron flow may occur from the —250 v. terminal of the power supply system through the switch 18, conductor 14, switch 12, resistor R4, terminal 24, resistor R14, from the cathode 66 to the plate 72, conductor 74, load resistor R15 to the +250 v. terminal of the power supply. The rate at which the pentode 60 increases its gain will be determined primarily by the relationship of the resistor R14 and condenser C6 and the parameters of the pentode 60, which may be of the 6W7G type. This electron flow is modulated by the signal from the generator 62, and the alternating component is transmitted by condenser C7 to the amplifying and translating means. The keys 10, 10.1, 10.2, etc., may be played to render a melody or to sound chords. Upon depression of any one of these keys the instrument will produce a percussion tone of limited duration and of a predetermined pitch, and this percussion tone will be accompanied by a sustained tone produced under the control of the pentode 60. The sustained tone may of course have its quality determined by various controls and may, if desired, have a volume control separate from that of the volume control 50. In some embodiments, however, the amplifiers 82 and 48 may be combined and be provided with a single volume control. When, however, the cost of production of the instrument is not a controlling factor it may be desirable to utilize separate amplifiers and speakers, since by thus separating the percussive tone output from the sustained tone output musically desirable acoustic perspective may be obtained and various tone modulating effects may be produced in either the percussive or the sustained tone output without affecting the other.

The instrument is of particular utility in the rendition of music having very rapid passages normally played on percussive mechanical instruments, and enables the performer to introduce a wide variety of tone color and intensity effects which cannot readily be obtained by the use of percussive mechanical instruments. Furthermore, the player is not limited in the rapidity with which successive notes may be played, as is frequently the case in playing percussive instruments where the weight and inertia of moving parts imposes an undesirable limitation upon the speed of operation and thus upon the technique of the artist.

In order to make it possible to play the instrument rapidly, the key action may be similar to that disclosed in the patent to G. H. Stephens, No. 2,260,412.

The instrument may be utilized to play chords or melodies, but when the potentiometer slide 30 is adjusted so that the signal impressed upon the grid 32 is of such value as to cause substantial distortion of the signal by the tube 34, the instrument becomes essentially of the melody type. This is because the tube is not capable of individually distorting a plurality of input signals of different fundamental frequencies without at the same time introducing other spurious summation and difference frequencies. Nevertheless, the effect of such distortion, under these circumstances, is not serious because the difference frequencies between the low frequency partials of a plurality of signals simultaneously impressed upon the grid 32 are of such short duration that an insufficient number of cycles of the low difference frequency are produced to make such frequency perceptible.

The tones are of such short duration that when chords are played, the effect of a percussive chord is nevertheless obtained. This is due to the fact that the musician cannot depress the keys in a manner such that all of the switches 12 will close at exactly the same instant. Thus, the various percussive tones of the chord will be produced in rapid succession and the listener will hear the tones produced in such close succession that the effect will be substantially the same as if a chord were being played. This effect may be enhanced by "rolling" the chord, that is, depressing the keys in very rapid succession starting either with the highest or lowest pitch key.

With the instrument of Figure 2, the controls 50 and 80 may be so set that the relative amplitudes of the percussive and sustained tones will be such as to produce a pronounced percussive effect or a slight percussive effect at the initiation of a sustained tone. If desired, the sustained tone control 80 may be adjusted to prevent transmission of the sustained tone signals to the amplifier 82, in which event the percussive tones alone will be produced, and for musical contrast purposes the controls 50 and 80 may, at all times, be so adjusted that the percussive tones will not be sounded while the sustained tones are sounded at full amplitude. The effect which is most interesting from a musical point of view is, however, that which is produced when the percussive tone is used in conjunction with and bends into the sustained tone.

While I have shown and described particular embodiments of my invention, it will be apparent to those skilled in the art that the more fundamental principles of the invention may be utilized in various types of electrical musical instruments. I therefore desire, by the following claims, to include within the scope of my invention all such similar and modified forms of my invention whereby substantially the results thereof may be obtained by the use of substantially the same or equivalent means.

I claim:

1. In an electrical musical instrument having electroacoustic translating means, the combination of a generator for producing a single electrical impulse containing a wide range of audio frequencies, means for filtering the output of said generator to pass a narrow band of the frequencies produced thereby, means for controlling the output of said generator, and means for transmitting said narrow band of frequencies to said electroacoustic translating means.

2. In an electrical musical instrument having an electroacoustic translating means, the combination of a source of direct current, a condenser normally charged by said source, manually controlled means for causing the sudden discharge of said condenser thereby to produce an electrical transient pulse, filtering means coupled to said condenser to attenuate frequencies above and below a predetermined frequency, a reactive mesh tuned to resonate at said predetermined frequency and coupled to said filtering means to attenuate all frequencies of the transient pulse except said predetermined frequency, an electron discharge device having an input circuit coupled to said reactive mesh, said device operating non-linearly when said signal from said reactive mesh is impressed thereon, and an output circuit for said device coupled to said electroacoustic translating means.

3. In an electrical musical instrument having electroacoustic translating means, the combination of a junction point, manually controlled means for producing a sudden change in direct current potential at said junction point, frequency selective means resonant at a predetermined frequency, means for coupling said frequency selective means to said manually controlled means, and means for coupling said frequency selective means to the electroacoustic translating means.

4. The combination set forth in claim 3 in which the means for coupling said frequency selective means to the electroacoustic translating means includes a non-linearly operating electron discharge device.

5. The combination set forth in claim 3 in which said means for coupling said frequency selective means to the electroacoustic translating means comprises non-linear means having a substantially uniform output wave shape characteristic relatively independent of the amplitude of the input signal.

6. The combination set forth in claim 3 in which said means for coupling said frequency selecting means to said electroacoustic translating means includes an electron discharge device operating non-linearly to produce an output wave of substantially square box-like shape despite wide variation in the amplitude of the input signal.

7. In an electrical musical instrument having electroacoustic translating means, the combination of a generator for producing an electrical impulse containing a wide range of audio frequencies, means for filtering the output of said generator to pass a narrow band of the frequencies produced thereby, a switch manually operable to render said generator effective to generate an electrical impulse, an iterative switch operative to render said generator repetitively effective, and means for transmitting said narrow band of frequencies to said electroacoustic translating means.

8. In an electrical musical instrument having an electroacoustic translating means, a normally discharged condenser, manually controlled means for causing the sudden discharge of said condenser thereby to produce an electrical transient pulse, filtering means connected to said condenser to attenuate frequencies above and below a predetermined frequency, a reactive mesh connected in circuit with said condenser and tuned to resonate at said predetermined

frequency and to attenuate all frequencies of said pulse except said predetermined frequency, an electron discharge device having an input circuit coupled to said reactive mesh, said device operating non-linearly when said signal from said reactive mesh is impressed thereon, and an output circuit for said device coupled to said electroacoustic translating means.

9. In an electrical musical instrument having electroacoustic translating means, the combination of a generator repetitively producing electrical impulses each containing a wide range of audio frequencies, manually controlled means for rendering said generator operative, means for filtering the output of said generator to pass a narrow band of the frequencies produced thereby, means for introducing harmonic distortion in the output of said generator, and means for coupling said last named means to said electroacoustic translating means.

10. In an electric musical instrument having electroacoustic translating means, the combination of a junction joint, manually controlled means for producing a sudden change in direct current potential at said junction point, frequency selective means resonant at a predetermined frequency, means for coupling said frequency selective means to said manually controlled means, and means including a non-linear distortion device for coupling said frequency selective means to said electroacoustic translating means.

11. In an electrical musical instrument having an electroacoustic translating means, a normally charged condenser, means for causing the sudden discharge of said condenser thereby to produce an electrical transient pulse, band pass filtering means connected to said condenser, a resonant reactive mesh tuned to resonate at a predetermined frequency within the band of frequencies passed by said filtering means and coupled to said filtering means, a sharp cutoff electron discharge device having an input circuit coupled to said reactive mesh, said device operating non-linearly when said signal from said reactive mesh is impressed thereon, and an output circuit for said device coupled to said electroacoustic translating means.

12. In an electrical musical instrument having electroacoustic translating means, the combination of a junction point, manually controlled means for producing a sudden change in direct current potential at said junction point, frequency selective means resonant at a predetermined frequency, means for coupling said frequency selective means to said key controlled means, means for coupling said frequency selective means to said electroacoustic translating means, a generator of an electrical signal corresponding to a sustained musical tone, an output circuit for said generator, and means responsive to a change in the direct current potential at said junction point to determine the amplitude of the signal supplied by said generator to its output circuit.

13. In an electrical musical instrument having an output system including electroacoustic translating means, the combination of key controlled means for generating an electrical transient pulse containing a wide range of audio frequencies, filtering means sharply tuned to a musical frequency and coupled to said generating means for attenuating all but a narrow band of frequencies, and means to introduce harmonic distortion in said narrow band of frequencies, said last named means having an input circuit coupled to said filtering means and having an output circuit coupled to the output system of the instrument.

14. The combination set forth in claim 13 in which the coupling between the input circuit of said harmonic distortion introducing means and the filtering means includes an adjustable potentiometer.

15. The combination set forth in claim 13 in which said harmonic distortion introducing means comprises a sharp cutoff electron discharge device having a control grid, and in which means are provided to vary the amplitude of the signal impressed upon said grid by varying the degree of coupling between said filtering means and said device.

16. In an electrical musical instrument having an output system including electroacoustic translating means, the combination of a playing key, means controlled by said playing key for generating an electrical transient pulse containing a wide range of audio frequencies, filtering means sharply tuned to a musical frequency and coupled to said generating means for attenuating all but a narrow band of frequencies, means to introduce harmonic distortion in said narrow band of frequencies, said last named means having an input circuit coupled to said filtering means and having an output circuit coupled to the output system of the instrument, means for producing a sustained tone of pitch approximating that to which said filtering means is tuned, and means operated by said key for rendering said sustained tone producing means effective.

JOHN M. HANERT.

CERTIFICATE OF CORRECTION.

Patent No. 2,342,338. February 22, 1944.

JOHN M. HANERT.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 13, for "at" read --as--; page 4, first column, line 55, for "bends" read --blends--; and second column, line 68, claim 8, for "discharged" read --charged--; page 5, first column, line 21, claim 10, for "electric" read --electrical--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of April, A. D. 1944.

Leslie Frazer

(Seal) Acting Commissioner of Patents.

CERTIFICATE OF CORRECTION.

Patent No. 2,342,338. February 22, 1944.

JOHN M. HANERT.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 2, first column, line 13, for "at" read --as--; page 4, first column, line 55, for "bends" read --blends--; and second column, line 68, claim 8, for "discharged" read --charged--; page 5, first column, line 21, claim 10, for "electric" read --electrical--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 25th day of April, A. D. 1944.

Leslie Frazer

(Seal) Acting Commissioner of Patents.