July 6, 1943. L. HAMMOND ET AL 2,323,392

ELECTRICAL MUSICAL INSTRUMENTS

Filed Dec. 5, 1940 2 Sheets-Sheet 1

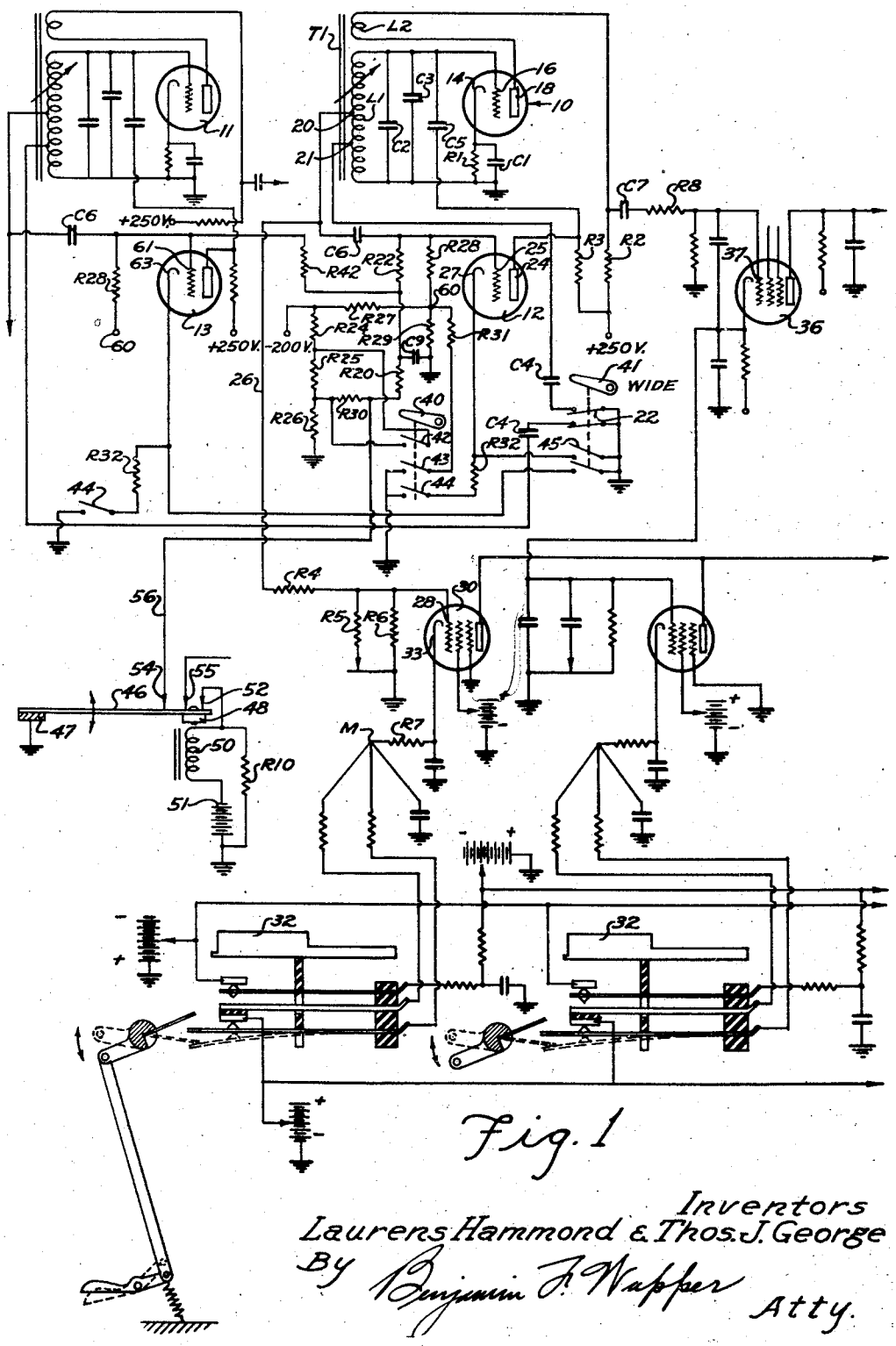


Fig. 1

Inventors
Laurens Hammond & Thos. J. George
By Benjamin F. Wapper Atty.

July 6, 1943. L. HAMMOND ET AL 2,323,392

ELECTRICAL MUSICAL INSTRUMENTS

Filed Dec. 5, 1940 2 Sheets-Sheet 2

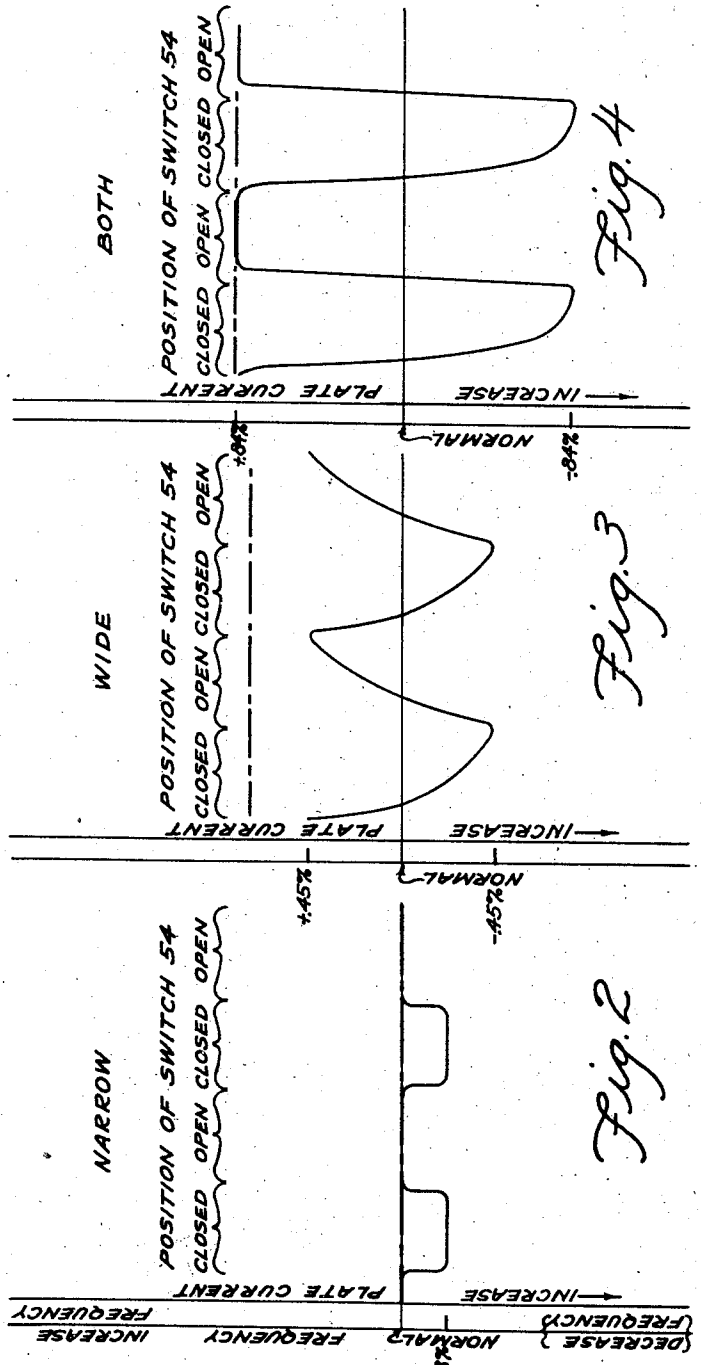


Fig. 4

Fig. 3

Fig. 2

Inventors
Laurens Hammond & Thos. J. George
By Benjamin F. Hupper Atty.

Patented July 6, 1943 2,323,392

UNITED STATES PATENT OFFICE

2,323,392

ELECTRICAL MUSICAL INSTRUMENT

Laurens Hammond and Thomas J. George, Chicago, Ill.; said George assignor to Hammond Instrument Company, Chicago, Ill., a corporation of Delaware

Application December 5, 1940, Serial No. 368,580

6 Claims. (Cl. 250—36)

Our invention relates generally to electrical musical instruments, and more particularly to improvements in vibrato producing apparatus for instruments of this type.

In instruments employing vacuum tube oscillators as the generators of the musical tone frequencies or as the means for stabilizing the frequencies of operation of the signal generators, it is desirable to provide means for varying the frequency of oscillation through a limited range, usually of less than a semi-tone, and at a periodicity of approximately 7 C. P. S., thereby to produce a vibrato effect. In the prior patent to Laurens Hammond No. 2,126,682 this result was accomplished by periodically opening and closing a circuit which intermittently provided added capacity in the oscillator tuning mesh, thereby altering the resonant frequency thereof. Due to the fact that this circuit was a part of the resonant tuning mesh, its opening and closing had a tendency to produce transients which were sometimes reflected as noise in the sound output of the instrument.

In accordance with the principles of our invention, the effective capacitance in the tuning mesh of the oscillator is varied at a vibrato periodicity, but by means which causes the variation to be gradual rather than abrupt. As a result, the shift in frequency of the oscillator is likewise at a gradual rate between its maximum and minimum frequencies.

It is thus an object of our invention to provide an improved vibrato apparatus for oscillators in which the frequency variation takes place at a sufficiently gradual rate so as to be free from undesirable transients.

A further object is to provide an improved vibrato apparatus in which the output circuit of an electron discharge device is utilized to provide the effect of a variable capacitance in the resonant tuning mesh of an oscillator.

A further object is to provide an improved vibrato apparatus for the oscillator generators of an electrical musical instrument in which the opening and closing of a direct current circuit is utilized to provide changes in the effective capacitance of the resonant tuning meshes of the oscillator generators.

A further object is to provide an improved means for changing the frequency of oscillation of a vacuum tube oscillator by means of a change of gain in a vacuum tube associated with the oscillator, which change in gain causes an apparent change in the capacitance forming part of the tuned circuit of the oscillator.

A further object is to provide an improved vibrato apparatus for electrical musical instruments in which there is a control to cause a narrow vibrato and a control to cause a wide vibrato, and in which operation of both controls will have an additive effect to produce an appreciably wider vibrato than that obtained by the operation of only the wide vibrato control.

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

Figure 1 is a wiring diagram of representative portions of an instrument embodying our invention; and

Figures 2, 3, and 4 are curves illustrating the extent of frequency variations obtained by the operation of the narrow vibrato control, the wide vibrato control, and both narrow and wide vibrato controls respectively.

The invention is herein described as applied to an instrument of the type disclosed in the aforesaid Hammond Patent No. 2,126,682, the instrument comprising a group of twelve master oscillators which generate the frequencies of the twelve highest notes of the instrument and are coupled to a cascaded series of frequency divider tubes by which the frequency of the master oscillator is successively halved, thereby to provide the frequencies of the successive lower octaves.

Referring to the drawings, tubes 10 and 11 together with their associated circuits form master oscillators, while tubes 12 and 13 are vibrato control tubes for the oscillator tubes 10 and 11 respectively. The tubes 10 to 13 are illustrated as triodes but for the purposes of economy are preferably of the twin triode type, the tubes 10 and 12 being preferably in a single envelope and constituting a twin triode, while the tubes 11 and 13 are similarly mounted in the same envelope. The oscillator tube 10 has a cathode 14, grid 16, and plate 18, the cathode 14 being connected to ground through a self-biasing resistor R1 which is shunted by a by-pass condenser C1.

A transformer T1 has a winding L1 connected between the grid 16 and ground, and a winding L2 connected between the plate 18 and a source of plate current indicated as a terminal +250 v. of the power supply system, the latter connection being made through a load resistor R2. The inductance L1 has condensers C2 and C3 connected in parallel therewith, these condensers, together with the effective inductance of the winding L1, constituting a resonant mesh determining the frequency of oscillation of the oscillator tube 10. The inductance L1 is preferably provided with an adjustable core so that the normal frequency of oscillation of the oscillator 10 may be adjusted initially to the standard musical frequency, or to be in tune with a mechanical musical instrument which cannot readily be tuned.

The inductance L1 has two taps 20 and 21, the tap 21 being normally connected through a compensating condenser C4 and switch 22 to ground, the condenser C4 thus normally being in

parallel with a portion of the winding L1. A condenser C5 is connected between the grid 16 and the plate 24 of the vibrato controlling tube 12, the plate 24 being connected to the terminal +250 v. of the power supply system through a load resistance R3.

The resistance R3 should be low with respect to the impedance of condenser C5, since these circuit elements are effectively connected in shunt with the tuned circuit. A resistor R3 of high value would thus tend to decrease the Q of the tuned circuit.

The tap 20, preferably at the center of the winding L1, is connected through a blocking condenser C6 to the grid 25 of the tube 12. A signal is also derived from the tap 20 through a conductor 26 which, through a resistor R4 is connected to the grid 28 of a control tube 30. As more fully disclosed in the aforesaid Patent No. 2,126,682 the control tube 30 has its operation controlled by a key 32 which, through a plurality of direct current meshes controlled by switches operated by the key, determines the potential upon a terminal M. The terminal M is connected to the cathode 33 of the tube 30 through a resistor R7, the characteristics of the tube 30 and its bias being such that said current flow takes place only during the positive peak portion of the signal impressed upon its grid 28. The amplitude of the signal wave impressed upon the grid 28 may be varied by optionally connecting a resistor R5 in parallel with a grid resistor R6 which connects the grid 28 to ground.

In addition to supplying a signal to the grid of the control tube 30, the oscillator tube 10 supplies a controlling signal to a divider tube 36, the associated circuits of which are such that it will operate to generate a frequency one half that of the frequency generated by the oscillator tube 10. The signal from the oscillator tube 10 is impressed upon the grid 37 of the divider tube 36 through a blocking condenser C7 and a resistor R8. Reference may be had to the aforesaid Patent No. 2,126,682 for a complete description of the construction and operation of the divider tubes and their associated circuits. Reference may be had to the patent to Hammond No. 2,126,464 for a further description of the construction and operation of the control tubes 30 and their associated key control circuits.

A narrow vibrato control element 40 and a wide vibrato control element 41 are mounted on a control panel within convenient reach of the player of the instrument, the control element 40, on being swung in a counterclockwise direction, being effective to close switches 42, 43 and 44, while the control element 41, when swung counterclockwise, being adapted to open switches 22 and close the switch 45.

When the wide vibrato control element 41 is operated, the compensating condenser C4 is rendered ineffective by the opening of the switch 22, while the cathode 27 of the tube 12 is connected to ground through the closure of the switch 45. Under these circumstances, as will appear more fully hereinafter, the amplification of the tube 12 is changed at a vibrato frequency. Since the plate 24 of the tube 12 is connected to the grid 16 of the oscillator tube 10 through the condenser C5, the variations in the gain of the tube 12 are reflected as an effective change in the capacitance of the condenser C5 in the resonant mesh of the oscillator tube 10.

The gain of the tube 12 is controlled by changing its grid bias at a vibrator frequency. Means for accomplishing this result comprises a reed 46, one end of which is fixed to a suitable grounded support 47, and the other end of which carries a weight 48, the weight being of magnetic material. The reed 46 is electromagnetically maintained in vibration by means of a driving magnet 50, one terminal of which is connected to a suitable current source 51, and the other terminal of which is connected to a contact 52. The contact 52 is adapted to make contact with the reed 47 when the latter is swung away from the driving electromagnet 50, and to shunt a resistor R10 which is normally in series with the coil of the driver 50 and the current source 51.

A pair of contacts forming switches 54, 55 are positioned to make contact with the reed 46 during approximately one half of the vibratory cycle of the latter. The contact 54 is connected by a conductor 56, resistors R20 and R22 with the grid 25 of the vibrator control tube 12.

The vibrato control tube 12 is normally biased beyond cutoff through a voltage divider mesh comprising resistors R24, R25 and R26 connected in series between a terminal —200 v. of the power supply system and ground, a resistor R27 connecting said terminal —200 v. to a junction point 60, a grid resistor R28 connecting the junction point 60 to the grid 25 of the tube 12, and a resistor R29 connecting the junction pint 60 to ground.

In addition, a resistor R30 is connected between the conductor 56 and the junction of resistors R25 and R26, while a resistor R31 is connected between the junction point 60 and one pole of the switch 43. A condenser C9 is connected between ground and the junction of resistors R20 and R22.

The following are illustrative of the values of the circuit elements which we have found satisfactory:

R1	ohms	20,000
R2	do	60,000
R3	do	50,000
R4	megohm	1
R5	ohms	75,000
R6	megohm	1
R7	do	1–5
R8	do	1
R20	ohms	500,000
R22	megohms	2
R24	ohms	75,000
R25	do	250,000
R26	do	10,000
R27	do	250,000
R28	megohms	3
R29	ohms	20,000
R30	do	250,000
R31	do	75,000
R32	do	15,000
R42	megohms	2
C1	microfarad	.1
C2	Depends on oscillator frequency	
C3	Depends on oscillator frequency	
C5	microfarad	.0001–.00005
C6	do	.001
C9	do	.025
Tubes 10—12, 11—13		6C8G

The operation of the apparatus will be described first under the narrow vibrato conditions, i. e., with the narrow vibrato control 40 swung counterclockwise from the position in which it is shown in Figure 1, while the wide vibrato control 41 remains in the position in which it is shown in said figure. Under these circumstances it will

be noted first that the cathode 27 (which is disconnected from ground when neither of the vibrato controls 40, 41 is operated), is connected to ground through the resistance R32; second, the potential on the conductor 56 is made more negative (when the switch 54 is open) due to the closure of the switch 42; and third, the junction point 60, being connected to ground through the resistor R31 and the closed switch 43, has its potential made less negative. The combined effect of these changes in potential, under the condition when the switch 54 is open, is to adjust the bias on the grid 25 of the tube 12 to just beyond cutoff. Then, when the switch 54 is closed by the reed 46, the potential of the grid is made sufficiently less negative to render the tube 12 conducting.

The audio signal derived from the tap 20 of the tuned circuit of the oscillator 10 is impressed upon the grid 25 of the tube 12 through the blocking condenser C6, amplified and fed back from the plate 24 through the condenser C5 to the grid of the oscillator tube 10. This signal impressed upon the grid 16 through the condenser C5 results in a decrease in the resonant frequency of the oscillator 10, as indicated by the curve of Figure 2.

In the curves of Figures 2, 3 and 4, there are in each instance two horizontal axes, the full line horizontal axes representing the normal frequency, increases in frequency being indicated above this line. The plate current of the tube 12 is indicated with reference to the dot-dash horizontal axes which represent zero plate current, increases in plate current being represented below these axes. It will be noted that in Figure 2, the normal frequency axis and the zero plate current axis coincide.

From Figure 2 it will be noted that when the switch 54 is closed, plate current flows through the tube 12 and the frequency is lowered slightly, whereas when the switch 54 is open, normal conditions prevail since there is no plate current flow through the tube 12. The maximum change in frequency effected by the use of the narrow vibrato may be in the order of .23% below the normal frequency.

The curve of Figure 3 illustrates the condition of operation when only the wide vibrato control 41 is operated so as to open switch 22 and close switch 45, the narrow vibrato control 40 being in the position shown in Figure 1. Under these circumstances, the frequency shift in the oscillator will range between a maximum of .45% above the normal frequency to .45% below the normal frequency. It will also be noted that the curve of Figure 3 shows that plate current flows both during the interval that the switch 54 is closed and while it is open.

The reason that the use of the wide vibrato causes the frequency to shift through a range extending from above to below the normal frequency is that when the wide vibrato control 41 is operated, the compensating condenser C4 is disconnected from the tuned circuit of the oscillator 10, and such disconnection results in increasing the frequency of oscillation to a value .45% greater than its normal frequency.

When the switch 54 is closed by the reed 46, the flow of plate current through the tube 12 causes an effective increase in capacitance in the tuned circuit of the oscillator 10, with the result that the frequency of oscillation is lowered to a minimum value of .45% less than the normal frequency, as shown by the curve of Figure 3. This change is frequency is not abrupt, but takes place in a smooth manner because of the filtering effect of the mesh associated with the condenser C9.

When the switch 54 is opened, the plate current decreases at a gradual rate, likewise because of the filtering effect of the condenser C9, and as a consequence the frequency of the oscillator 10 increases at a gradual rate to a value .45% above its normal frequency.

Figure 4 illustrates the operating conditions when both the narrow vibrato control and the wide vibrato control are operated. Under these circumstances the frequency of oscillation of the oscillator 10 is varied between a value .84% above the normal frequency to .84% below the normal frequency. When the switch 54 is closed plate current commences flowing through the tube 12, thus effectively increasing the capacitance in the tuned circuit of the oscillator 10, and thereby reducing its frequency, the condenser C9 and its associated mesh making this change gradual.

When the switch 54 is open, the tube is cut off and the plate current stops, but such stoppage of current flow is so gradual, due to the use of the filtering mesh including condenser C9, that no undesirable transients are produced. The frequency change corresponds to the change in plate current, and hence there is no suddent shift in the frequency of the oscillator 10 as is clearly illustrated by the curve of Figure 4.

The three curves of Figs. 2, 3, and 4 each illustrate clearly the fact that the frequency shift in the oscillator 10 is at a more or less gradual rate and never instantaneous, from which it will be apparent that undesirable transients in the output of the oscillator 10 will not be produced.

In the foregoing description it has been assumed that an increase in plate current to the tube 12 will result in a corresponding decrease in the frequency of the oscillator 10. This effect may be explained by the following considerations:

The apparent capacity of the condenser C5, as looking from the grid 16 of the tube 10, changes with the gain of the vibrato control tube 12. For purposes of explanation, let it be assumed that the grid 16 of the tube 10 is being driven positive to a potential of +1 volt by the tuned circuit L1, C2, and C3 considered as a generator. Assume further that the tap 20 is a center tap of the winding L1. The grid 25 of the tube 12 will therefore change potential in the same direction as the grid 16, but to one half the amplitude, under the conditions assumed to +½ volt. Depending upon the gain of the tube 12, the potential on plate 24 of the tube 12 will move negatively to a value equal to the gain of the tube times ½ volt, and assuming the gain of this tube to be 20, the plate 24, at the instant assumed, will be at a potential of 10 volts negative with respect to its normal potential. Thus, at this instant, the terminal of the condenser C5 which is connected to the grid 16 has a potential of +1 volt thereon, while the terminal of this condenser which is connected to the plate 24 has a potential of 10 volts more negative than its normal voltage. The potential across the terminals of the condenser C5 is thus 11 volts as compared to 1 volt across the tuned circuit. Under these conditions, the tuned circuit must therefore charge condenser C5 at a rate 11 times as fast as it would if the terminal of condenser C5, which connects to plate 25, were connected to ground. The result therefore is that condenser C5 appears to

the tuned circuit to have a capacity 11 times its actual capacity.

In the complete instrument there will of course be twelve tubes corresponding to the tubes 12 and 13, that is, one for each semi-tone interval of an octave. Each tube 12, 13 will have associated therewith a condenser C4, switch 22, switch 45, switch 44, and resistors R22, R28, R32 and R3. Each pair of tubes, such as the pair of tubes 12 and 13, will have associated with it a switch such as 54, 55, resistors R30 and R20, and condenser C9. The voltage divider resistors R24, R25, R26 and the resistors R27 and R31 may be common to the twelve vibrato control tubes. The switches 42 and 43 may likewise be common to the circuits for all of the vibrato control tubes of the instrument.

While we have shown and described a particular form of the invention, and have set forth illustrative values of the circuit elements, it will be apparent to those skilled in the art that the values of the circuit elements may be varied considerably, particularly if compensatory changes are made in other elements of the circuits, and that the underlying principles of the invention may be embodied in a variety of equivalent forms. We therefore desire by the following claims to include within the scope of our invention all such modifications and variations of our invention by which substantially the results of the invention may be obtained by the use of substantially the same or equivalent means.

We claim:

1. For use in an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency in which said oscillator has a tuned circuit, the combination of an electron discharge device having a cathode, grid and plate, said device having an input and an output circuit, a circuit coupling the input circuit of said device to said tuned circuit, a condenser, a circuit connecting the output circuit of said device to said tuned circuit through said condenser, and means to vary the gain of said electron discharge device at a vibrato periodicity, said means comprising a voltage divider having one terminal maintained at a potential sufficiently negative to bias such device beyond a cutoff and its other terminal connected to the cathode of said device, a resistance network connecting said first named terminal of said voltage divider to said grid, a switch operated at a vibrato periodicity, a resistance and capacitance network connected between said grid, an intermediate point on said voltage divider, and one pole of said switch, and means connecting the other pole of said switch to said cathode.

2. For use in an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency, in which said oscillator has a tuned circuit, the combination of an electron discharge device having a cathode, grid, and plate, said device having an input and an output circuit, a circuit coupling the input circuit of said device to said tuned circuit, a condenser, a circuit connecting said condenser and the output circuit of said device across said tuned circuit, and means to vary the gain of said electron discharge device at a vibrato periodicity, said means comprising, a voltage dividing network connected to said grid for determining the bias thereof, a switch, means to close and open said switch at a vibrato rate, and a circuit including said switch and connecting said voltage dividing network to a point at a potential sufficiently high to raise the potential on said grid above cutoff.

3. For use in an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency in which said oscillator has a tuned circuit, the combination of an electron discharge device having a cathode, grid and plate, an input and an output circuit for said device, a circuit coupling the input circuit of said device to said tuned circuit, a condenser, a circuit connecting the output circuit of said device to said tuned circuit through said condenser, and means to vary the gain of said electron discharge device at a vibrato periodicity, said means comprising a source of potential of sufficiently negative value to bias such grid beyond cutoff, a manually operable control element, a resistance network connected between said source, said grid, and a point of fixed direct current potential, means operated by said control element to render said device operative and to change said network in a manner to cause an increase in the potential on said grid to a value above cutoff potential, a switch, means for opening and closing said switch at a vibrato periodicity, a point of fixed direct current potential above the cutoff potential, and a circuit including said switch to connect said network to said point, thereby to raise the potential of said grid during the interval that said switch is closed.

4. For use in an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency, in which the oscillator has a tuned circuit, the combination of an electron discharge device, means to vary the gain of said device at a vibrato periodicity, said device having an input and an output circuit, a circuit coupling the input circuit of said device to said tuned circuit, a condenser, a circuit connecting said condenser and the output circuit of said device across said tuned circuit, a compensating condenser, a first switch connecting said compensating condenser to said tuned circuit, a second switch controlling the operation of said electron discharge device, and a manually operable control element to open said first switch and close said second switch to render said gain varying means effective.

5. For use in an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency in which said oscillator has a tuned circuit, the combination of an electron discharge device having a cathode, grid and plate, said device having an input and an output circuit, a circuit coupling the input circuit of said device to said tuned circuit, a condenser, a circuit connecting the output circuit of said device to said tuned circuit through said condenser, and means to vary the gain of said electron discharge device at a vibrato periodicity, said means comprising, a source of biasing potential for said device, a resistance network connected between said source and said grid normally to maintain said grid biased beyond cutoff, a periodically closed switch connected to said network to raise the potential on said grid to a value above cutoff potential whenever the switch is closed, and a condenser connected to said network to prevent abrupt changes in the potential on said grid.

6. In an electrical musical instrument having an electron discharge tube oscillator for generating electrical impulses of musical frequency in

which the oscillator has a tuned circuit determining its frequency of oscillation, the combination of an electron discharge device, means to vary the gain of said device at a vibrato periodicity, said device having input terminals and output terminals, means connecting the input terminals of said device to said tuned circuit, a condenser, means including said condenser connecting said output terminals to said tuned circuit, a wide vibrato control element, a narrow vibrato control element, circuits controlled by said elements selectively to change the range of variations in gain produced by said gain varying means, a reactance in said tuned circuit, and means operated simultaneously with said wide vibrato control element for rendering said reactance ineffective, thereby to compensate for the shift in average frequency of the oscillator which would otherwise take place upon operation of said wide vibrato control element.

LAURENS HAMMOND.
THOS. J. GEORGE.