

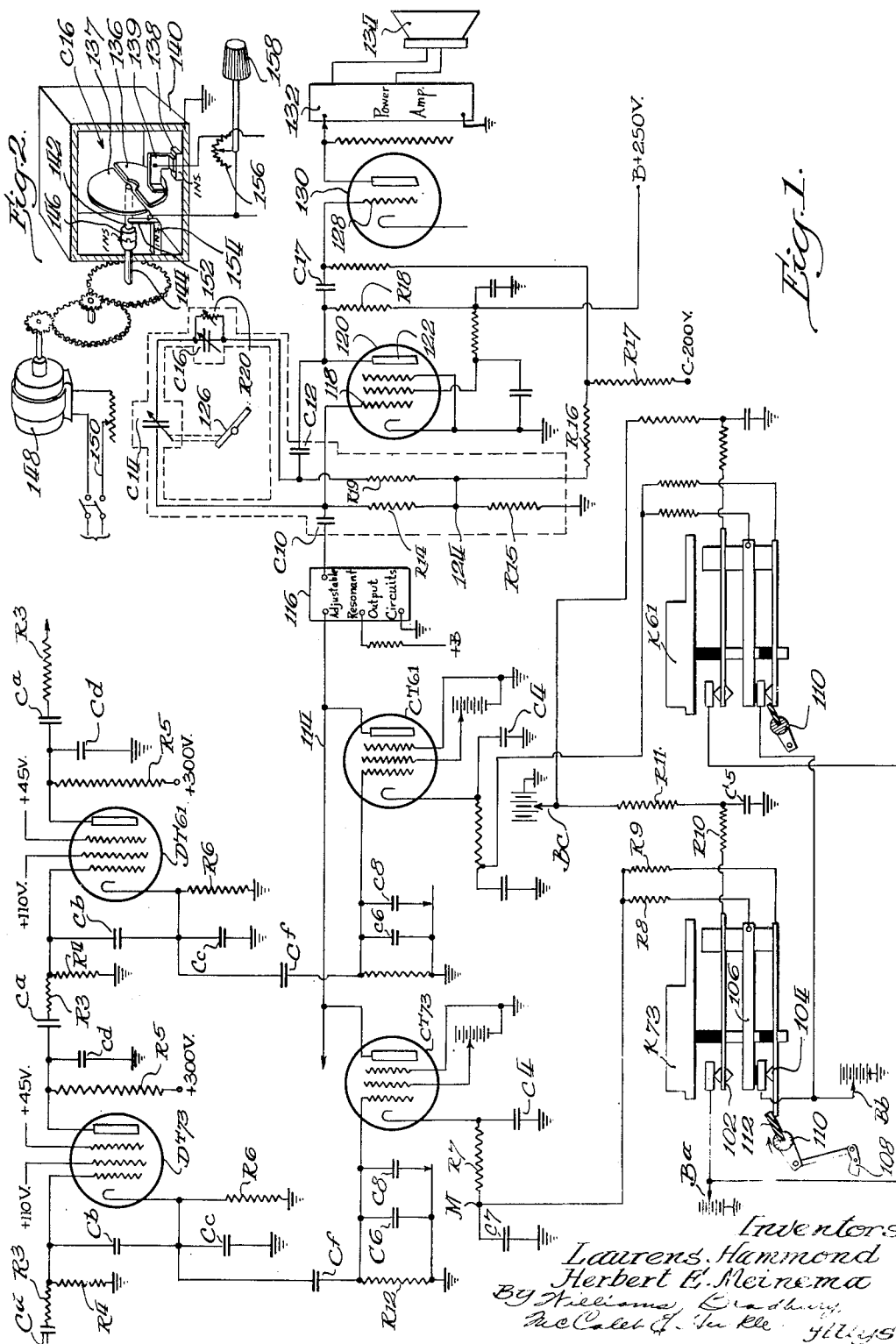
Nov. 12, 1940.

L. HAMMOND ET AL

2,221,188

ELECTRICAL MUSICAL INSTRUMENT

Filed Nov. 17, 1958



UNITED STATES PATENT OFFICE

2,221,188

ELECTRICAL MUSICAL INSTRUMENT

Laurens Hammond and Herbert E. Meinema, Chicago, Ill.; said Meinema assignor to Hammond Instrument Company, Chicago, Ill., a corporation of Delaware

Application November 17, 1938, Serial No. 240,889

17 Claims. (Cl. 84—1.24)

Our invention relates generally to electrical musical instruments, and more particularly to improved swell or intensity control circuits and apparatus for instruments of this type.

5 It is desirable in an electrical musical instrument that means be provided for varying the intensity or volume of the over-all acoustic output of the instrument by relatively small increments, it being preferable that the increments be of such small value that they are not perceptible to the ordinary listener. The apparatus should be of such construction that it is very durable and that it does not introduce transients in the output. An ordinary variable resistance or potentiometer in the output circuit is not fully satisfactory because of the rapid mechanical wear of the slider and the resistance, and because of the possibility of accumulation of dirt tending to impair the electrical contacts. While a variable resistance of this character is satisfactory for radio receivers and similar apparatus, the almost constant use of the swell or expression pedal by an organist renders this type of control unsatisfactory for organs. Similar difficulties appear in connection with the tremulant apparatus which may be considered as a periodically varying intensity or volume control device.

An improved apparatus for the swell or expression pedal of an instrument of this character is disclosed in the application of Laurens Hammond, Serial No. 91,284, filed July 18, 1936, wherein the difficulty of mechanical wear is substantially obviated, but in which the increments of impedance control by the swell pedal are relatively large if the number of switch contacts is to be reduced to a number which makes the apparatus reasonable in cost.

These disadvantages of prior swell control apparatus for electrical musical instruments are overcome by our invention wherein the incremental changes in intensity of the output may be infinitely small, depending solely upon the operation of the swell pedal by the musician. The apparatus is also free from parts subjected to appreciable mechanical wear, and thus the apparatus will outlast the instrument as a whole. Furthermore, its operation does not introduce undesirable transients.

50 It is thus an object of our invention to provide an improved swell control apparatus for electrical musical instruments which is very durable, may be manufactured at a low cost, and which is capable of controlling the amplitude of the output signal by substantially infinitely small in-

crements without the introduction of undesirable transients.

A further object is to produce an improved tremulant apparatus for electrical musical instruments.

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

Figure 1 is a wiring diagram of representative portions of a complete electrical musical instrument showing particularly the swell or volume control circuit; and

Figure 2 is a diagrammatic view of a tremulant producing mechanism which may be incorporated with the swell control apparatus.

Referring to Figure 1, the instrument includes a plurality of divider tubes DT73 and DT61 which are representative of a complete set of tubes, one for each note of the musical scale, and which are arranged in stages in such manner that the frequency delivered by each tube is controlled by a preceding stage delivering a signal having twice the frequency of that supplied by the controlled stage. Thus, in the complete instrument there are 12 vacuum tube oscillators, or other similar sources of electrical impulses of the frequencies of the twelve highest notes of the musical scale, and each of these sources will supply a controlling signal to the highest of a plurality of cascaded stages for the corresponding octave notes of the instrument.

The tubes DT73 and DT61 are representative of two such stages, the signal from a controlling source to the tube DT73 being impressed upon the grid thereof through a condenser Ca and resistance R3, the grid being connected to ground through a high resistance R4. The cathode of the tube DT73 is connected to ground through a resistor R6 and a condenser Cc, and is connected to the grid by a condenser Cb. The plate of the tube DT73 is supplied with current from a suitable source indicated as "+300 V.", is connected to ground through a condenser Cd, and supplies a signal to the grid circuit of the tube DT61 of the following stage through a condenser Ca and a resistance R3 in the same manner as the tube DT73 receives a signal from the controlling source. This system of generating the various frequencies of the musical scale is disclosed and claimed in greater detail in a patent to Laurens Hammond No. 2,126,682.

The signal used for the production of the note is derived from the tubes DT61 and DT73 through condensers Cf connected to the cathodes of these tubes. These signals are impressed re-

spectively upon the grids of control tubes CT61 and CT73, the wave form being changed as desired by resistors R12 and condensers C6 and C8 which are connected in parallel with the resistor R12 between the grid of tube CT61 and CT73 and ground. The condensers C8 are provided with gang switches by which they may be simultaneously disconnected from the circuit.

The signals from the divider tubes are thus continuously impressed upon the grids of the control tubes but the latter are normally biased so as to be non-conducting and are rendered conductive only upon operation of key controlled switches by which the cathode-plate current of these tubes is controlled in a manner to determine the intensity envelopes of the notes. This key controlled switching means comprises manually operable keys K61 and K73 which control the plate-cathode current, which is supplied from a plurality of sources of adjustable direct current potential Ba, Bb and Bc. The source Ba is normally connected to a condenser C5 through a resistance R10 and switch 102, while the source Bb is connected through a switch 104 and resistance R9 to a terminal M which in turn is connected to the cathode of the tube CT73 through a resistance R7, the cathode being connected to ground through a condenser C4. A condenser C7 connects the terminal M to ground.

The switch 102 is adapted upon depression of the key to make contact with a fixed switch arm 106 which is connected to the terminal M through a resistance R8, whereupon the potential of source Bc is impressed upon the terminal M through a resistance R11, the resistance R10 and the resistor R8. By this means, the intensity envelope of the note is controllable, as more fully disclosed and claimed in the patent to Laurens Hammond No. 2,126,464.

The switch 104, when closed, permits the potential of the point M to rise sufficiently so that the control tube will be cut off, the rate at which the potential of the terminal M rises being determined in part by the resistance R9. When it is desired to sustain the notes, a sustaining pedal 108 is operated to swing a rock shaft 110 clockwise and, through an insulating strip 112 carried by the shaft, depress the flexible arms of switches 104. Under these circumstances, the potential source Bb is disconnected from the terminal M, and the note will continue to sound after the key is released until the flow of current through the resistor R7 depletes the charge of the condenser C7.

The plates of the control tube CT61 and CT73 are illustrated as connected to a common conductor 114 which leads to adjustable resonant output circuits illustrated by a block 116. A plurality of conductors 114 are provided, each connected to the plates of a plurality of the control tubes so that the adjustable resonant circuits may be individually controlled for groups of notes.

The composite signal from all of the control tubes, as modified by the adjustable resonant output circuits, is connected to a preamplifier through a blocking condenser C10, being connected to the grid 118 of a tube 120 in the first stage of the amplifier. The grid 118 is connected through a grid resistor R14 to a source of biasing potential provided by the resistance network R15, R16, R17, the latter being connected to a biasing potential source indicated as being of -200 volts. The plate supply is indicated as provided by a source marked B +250 volts, being

connected to the plate through a plate resistor R18.

Connected between the grid 118 and the plate 122 of the tube 120 is a network consisting of a blocking condenser C12 and variable condensers C14 and C16 connected in series with the condenser C12, the condenser C16 being shunted by a variable resistance R20. A resistor R19 is connected between the condenser C12 and the junction point 124. The plate to grid circuit which includes the condensers C12, C14 and C16 forms an adjustable degenerative or inverse feedback. The variable condenser C14 is controlled by a swell pedal 126 through a suitable actuating linkage, and the condenser C16 and its shunting resistance R20 are provided to produce an adjustable tremulant effect as will be pointed out hereinafter.

The values of the elements of the circuit are such that the degenerative feedback may be varied from substantially zero feedback to substantially 100% feedback. Since the variable condenser C14 is positioned in this feedback circuit, it may be of relatively small value, and may thus be of the air dielectric type customarily used for radio frequency tuning. The values of the condensers C12, C14, C16 are resistors R19, R14, are such that the degenerative feedback is substantially uniform for all frequencies within the range of the instrument, although if variable frequency distortion is desired, this mesh may be modified to introduce such distortion.

The cathode, screen and suppressor of the tube 120 are connected in the usual manner, and the plate 122 is connected to the grid 128 of a tube 130 forming the next stage of the preamplifier through a blocking condenser C17. The output of the preamplifier (which may include additional stages) is connected to a power amplifier 132, which in turn supplies the amplified signal to the speaker 134.

The condenser C16 for providing the tremulant is shown in Figure 2 as comprising a pair of semi-circular or segmental plates 136 and 137, the plate 136 being secured to an insulating block 138 by a bracket 139, mounted in a housing 140. The plate 137 is carried on the end of a shaft 142 which is insulated from its driving shaft 144 by an insulating coupling 146. The shaft 144 is driven through a suitable speed reducing gear train from a motor 148, the supply of current to which is controlled by a rheostat 150 to permit adjustment of the speed of the motor. A brush 152 is mounted on an insulating block 154 within the housing 140. The brush 152 and the bracket 139 thus form the terminals of the condenser, and leads from these terminals are shunted by a variable resistor 156 operated by a control knob 158.

The plate 137 is preferably rotated at a speed in the order of 7 c. p. s. The degree of feedback is thus periodically varied, and hence produces a periodic variation in the intensity of the sound produced by the loud speaker 134. By proper adjustment of the control knob 158, the degree of amplitude variation produced by the condenser C16 may be varied from substantially zero to a value which will cause a pronounced tremulant in the music produced by the instrument.

Since the condenser C16 is in series with the condenser C14, its effect on the signal feedback will be greatest when the condenser C14 is adjusted to its maximum capacitance, (minimum reactance), and conversely, when the condenser

C14 is adjusted to minimum capacitance (maximum reactance), the effect of the periodic variations of the capacity of condenser C16 upon the feedback will be least.

Thus, the periodic variations in the capacity of the condenser C16 will have relatively little effect on the gain of the amplifier when the swell pedal is open (maximum sound intensity), and a relatively great effect when the swell is nearly closed (minimum sound intensity). Of course the effectiveness of the variations in the capacity of condenser C16 will change correspondingly for intermediate positions of the swell pedal. This is a desirable characteristic since, from the point of view of the musician, a pronounced tremulant is much less desirable in music played forte or fortissimo than in music played piano or pianissimo.

By proper adjustment of the control knob 158, the degree of amplitude variation produced by the condenser C16 may be varied from substantially zero to a value which will cause a very pronounced tremulant in the music produced by the instrument.

The following are given as illustrations of the values of resistors and condensers which may be used in the first stage of the preamplifier, it being understood that these values may be varied considerably without materially affecting the operation of the apparatus:

R14.....	5 megohms
R15.....	2000 ohms
R16.....	5000 ohms
R17.....	150,000 ohms
R18.....	350,000 ohms
R19.....	1 megohm
R20.....	0-100,000 ohms
C10.....	.0002 microfarad
C12.....	.05 microfarad
C17.....	.02 microfarad
C14.....	variable 10 to 500 micro microfarads
C16.....	variable 10 to 1000 micro microfarad

From the above description, it will be apparent that as the capacitance of the condenser C14 is increased, the amplitude of the signal fed back from the plate 132 to the grid 118 of the tube 120 will be increased, and since the plate signal is substantially 180° out of phase with respect to the signal supplied to the grid through the condenser C10, the latter signal will be attenuated to a degree dependent upon the setting of the condenser C14. Similarly, when rendered effective by adjustment of the control knob 158, the rotating plate condenser C16 will cause periodic variation in the intensity of the feedback signal impressed on the grid 118 and thus produce the desired tremulant effect in the sound output of the instrument.

The feedback mesh is of such character and its elements of such value, that the frequency distortion introduced is negligible. In some instruments it may, however, be desirable to provide elements of such values that the bass notes are attenuated with respect to the treble notes as the overall intensity is increased. Since the capacities of the condensers C14 and C16 are varied by infinitely small increments, their operation will not introduce undesirable transients.

The degenerative feedback circuit is illustrated as receiving its feedback signal from the first tube of the preamplifier. It will be apparent, however, that the feedback circuit might well be connected to the plate of the third tube of the preamplifier, or to any other point in the preamplifier

circuit in which the signal is substantially 180° out of phase with respect to the signal supplied to the grid in the first stage of the preamplifier. Similarly, the feedback circuit might be applied to a tube other than that of the first stage of the preamplifier. However, it has been found that the circuit arrangement illustrated is productive of very satisfactory results, and that it has some advantages over the slightly modified circuit arrangements which might be used to accomplish substantially the same results.

We therefore intend, in the following claims, to include within the scope of our invention, all such equivalent circuits and arrangements whereby substantially the results of our invention may be obtained by substantially the same means.

We claim:

1. For use with an electrical musical instrument having a plurality of generators of electrical impulses of the frequencies of the musical scale, a signal output circuit, and selectively operable means to control transmission of impulses from said generators to said output circuit; an amplifier having a multi-electrode electron discharge device including a cathode, grid and plate, an input circuit and an output circuit for said device, means for impressing the signal from said signal output circuit upon the input circuit of said device, a swell pedal, a degenerative feedback circuit from the output circuit of said device to the input circuit thereof, said feedback circuit including a variable condenser operated by said swell pedal, and electroacoustic translating means connected to the output circuit of said device.

2. The combination set forth in claim 1, in which an additional variable condenser is connected in series with said swell pedal operated variable condenser, and means are provided selectively to vary the effective capacitance of said additional variable condenser at a periodic rate.

3. The combination set forth in claim 1, in which said degenerative feedback circuit includes a fixed condenser connected to the plate of said device in series with said swell pedal controlled variable condenser, and in which there is a high resistance circuit connected between the respective plates of said condensers which are connected together and the cathode of said device.

4. The combination set forth in claim 1, in which said signal output circuit is connected to the input circuit of said device through a blocking condenser, and in which said degenerative feedback circuit is substantially free from undesirable frequency distortion throughout the musical frequency range.

5. In an electrical musical instrument having means for electrically generating and controlling a musical signal, an amplifier connected to said generating and controlling means to amplify said signal, said amplifier including an electron discharge device having a cathode, plate and grid, a point in said amplifier in which the signal is substantially 180° out of phase with respect to the signal supplied thereto, a degenerative feedback circuit from said point to the grid of said device, said circuit including a periodically variable condenser to cause periodic variation in the amplitude of the signal in the output of said device, thereby to produce a tremulant effect.

6. The combination set forth in claim 5 in which said variable condenser comprises a pair of plates, and a motor is provided for moving one of said plates periodically to vary the effective

capacitance of said condenser and thereby to cause periodic variation in the gain of said device for the purpose of producing a tremulant effect.

7. The combination set forth in claim 5 in which said variable condenser comprises a relatively fixed plate, a cyclically movable plate, and in which said variable condenser is shunted by a manually variable resistance thereby to vary the effectiveness of the periodic changes in capacity of said variable condenser to produce a tremulant effect.

8. The combination set forth in claim 5 in which said variable condenser is provided with a resistor shunt for manually adjusting the effectiveness of said capacitance, and in addition, is provided with power operated means for varying its effective capacitance at a tremulant periodicity.

9. In an electrical musical instrument, the combination of means for generating and controlling a signal translatable into musical sound, means for amplifying said signal including an electron discharge device having an input circuit connected to said means for generating and controlling said signal and an output circuit, electro-acoustic translating means connected to said output circuit, and a variable degenerative feedback circuit between said output circuit and said input circuit and operable substantially uniformly to vary the gain of said device throughout the frequency range of the signals produced by said signal generating and controlling means.

10. The combination set forth in claim 9 in which said degenerative feedback circuit includes a periodically varying reactance effective periodically to vary the degree of feedback and thereby to produce a tremulant effect in the output circuit.

11. The combination set forth in claim 9 in which said degenerative feedback circuit includes two variable reactances, one of which is manually adjustable and the other of which is provided with means for periodically varying its reactance, and with means for adjusting its effectiveness, thereby to vary the effective gain of said amplifier and to produce an adjustable tremulant effect.

12. The combination set forth in claim 9, in which said degenerative feedback circuit includes a variable reactance effective to vary the degree of feedback, and a swell control device is provided for controlling said variable reactance.

13. A volume control device for electrical musical instruments in which the output is transmitted through an amplifying electron discharge device having a cathode, grid and plate, comprising a variable condenser, and an inverse feedback circuit connecting said condenser between the plate and the grid of said device.

14. In an electrical musical instrument having a signal output circuit and having means for amplifying and translating into sound electrical signal impulses, the combination of an electron discharge device having a cathode, grid and plate, a condenser connecting said grid to the signal

output circuit of said instrument, a circuit connecting the plate of said device to said amplifying and translating means, a terminal at which the signal is substantially 180° out of phase with respect to the signal on said grid, and means to control the acoustic output volume of said translating means comprising a circuit connecting said terminal to said grid, said circuit including a variable condenser, and an expression pedal associated with said instrument for operating said variable condenser.

15. In an electrical musical instrument having a signal output circuit and having means for amplifying and translating into sound electrical signal impulses, the combination of an electron discharge device having a cathode, grid and plate, a condenser connecting said grid to the signal output circuit of said instrument, a circuit connecting the plate of said device to said amplifying and translating means, and means to control the acoustic output volume of said translating means comprising, a feed-back circuit connecting the plate of said device to the grid thereof, said feed-back circuit including a variable condenser in series, an expression pedal associated with said instrument for operating said variable condenser, and a high impedance circuit connecting the grid of said device to the cathode thereof.

16. In an electrical musical instrument having a signal output circuit and having means for amplifying and translating into sound electrical signal impulses, the combination of an electron discharge device having a cathode, grid and plate, a condenser connecting said grid to the signal output circuit of said instrument, a circuit connecting the plate of said device to said amplifying and translating means, and means to control the acoustic output volume of said translating means comprising, a feed-back circuit connecting the plate of said device to the grid thereof, said feed-back circuit including a variable condenser in series, optionally operable means for continuously varying said variable condenser at a tremulant rate, and a high impedance circuit connecting the grid and cathode of said device.

17. In an electrical musical instrument having a signal output circuit and having means for amplifying and translating into sound electrical signal impulses, the combination of an electron discharge device having a cathode, grid and plate, a condenser connecting said grid to the signal output circuit of said instrument, a circuit connecting the plate of said device to said amplifying and translating means, and means to control the acoustic output volume of said translating means comprising, a feed-back circuit connecting the plate of said device to the grid thereof, said feed-back circuit including a variable condenser in series, optionally operable means for continuously varying said variable condenser at a tremulant rate, an adjustable resistance shunting said variable condenser, and a high impedance circuit connecting the grid and cathode of said device.

LAURENS HAMMOND.
HERBERT E. MEINEMA.