March 17, 1942. J. M. HANERT 2,276,390

ELECTRICAL MUSICAL INSTRUMENT

Filed Oct. 14, 1940 3 Sheets-Sheet 1

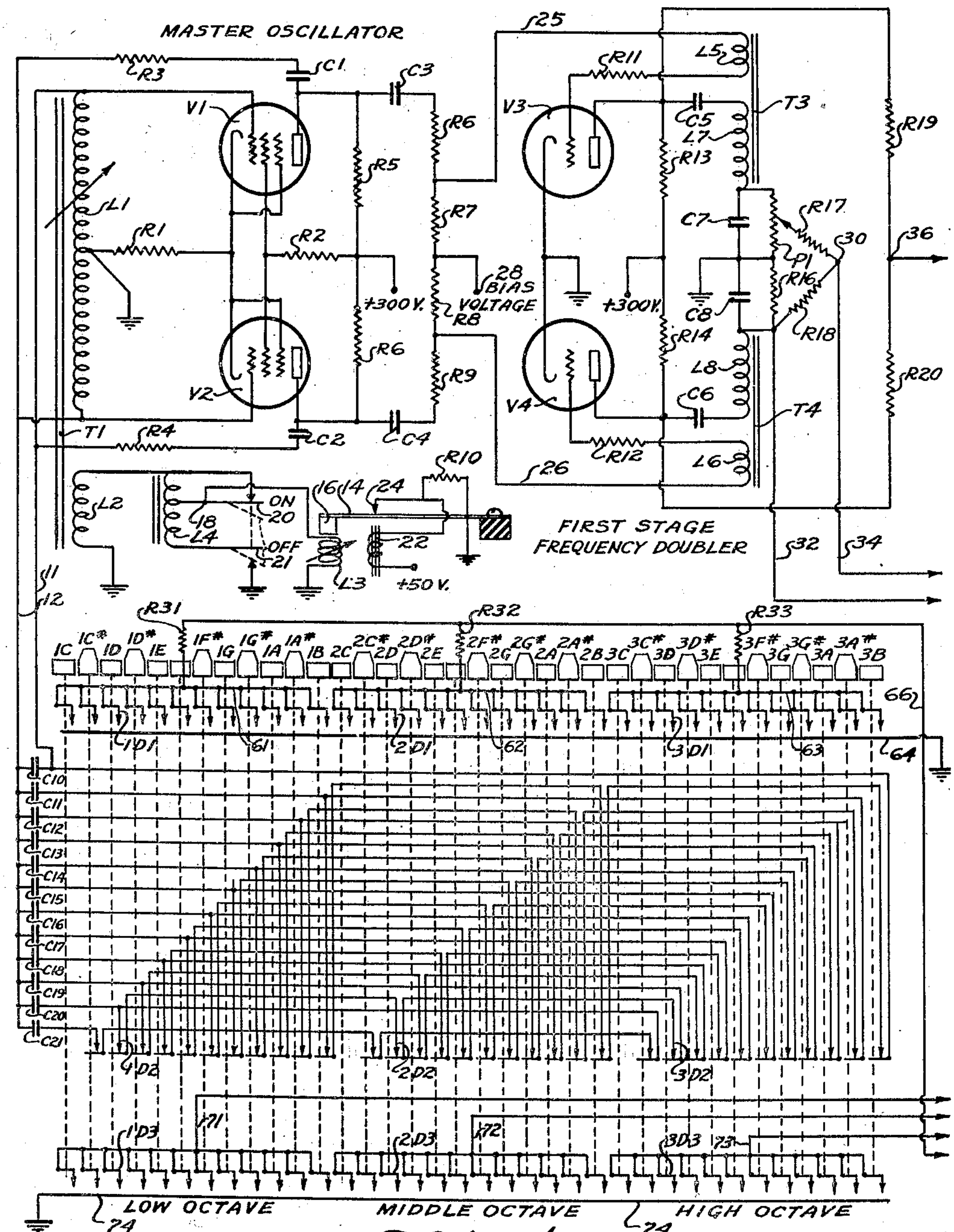

Fig. 1

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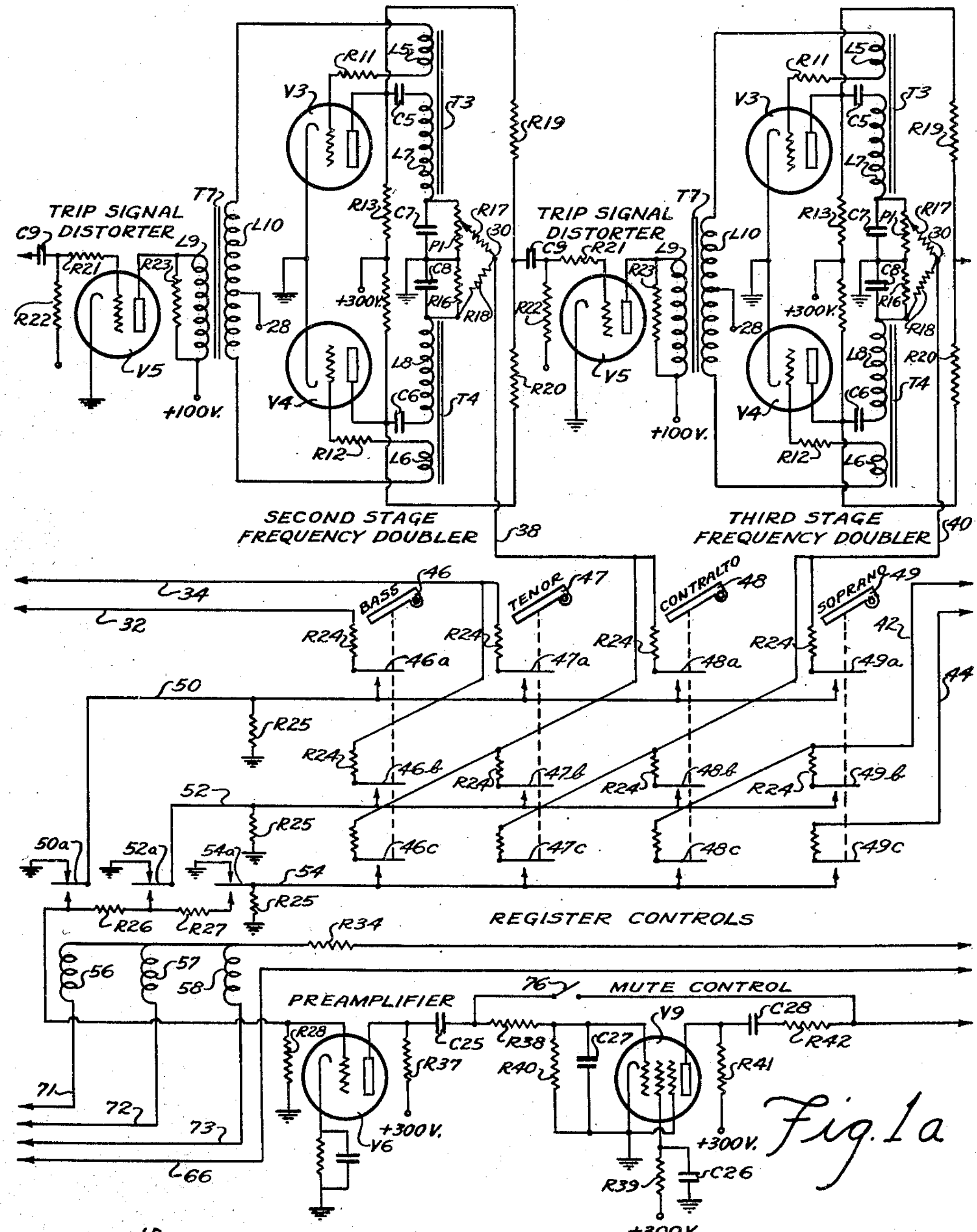

Fig. 1a

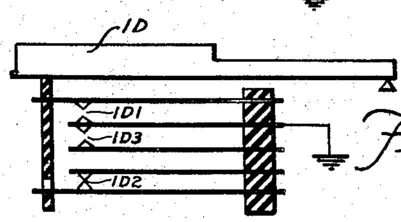

Fig. 3

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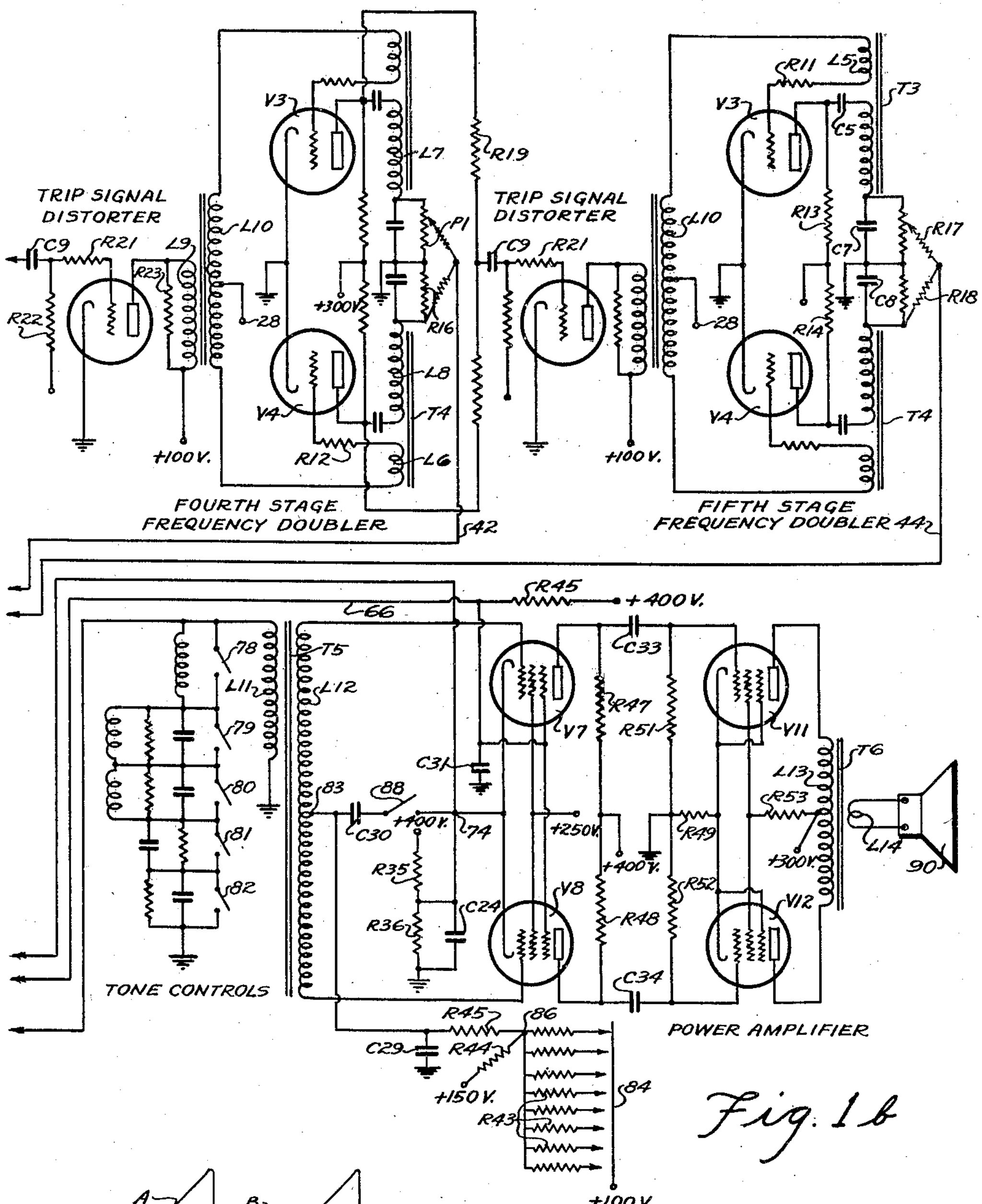

Fig. 1b

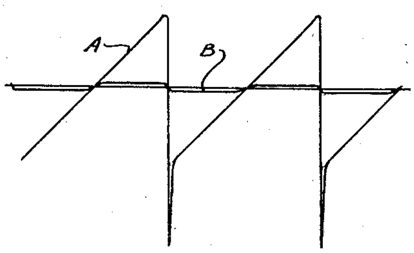

Fig. 2

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Patented Mar. 17, 1942

2,276,390

UNITED STATES PATENT OFFICE

2,276,390

ELECTRICAL MUSICAL INSTRUMENT

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

Application October 14, 1940, Serial No. 361,064

14 Claims. (Cl. 84—1.11)

My invention relates generally to electrical musical instruments, and more particularly to instruments of this type adapted for the playing of melodies as distinguished from instruments on which chords may be played.

It is an object of my invention to provide an improved frequency generating system for a melody type electrical musical instrument.

A further object is to provide an improved frequency interlocked cascaded oscillator system in which the frequency is successively doubled, from stage to stage, to provide a series of octave interval frequencies.

A further object is to provide an improved frequency generating system employing a plurality of frequency doubling cascaded stages, each generating a substantially saw-tooth wave shape which is musically desirable, and providing interstage coupling means which distorts the trip signal wave into a wave shape which is substantially symmetrical about its vertical axis.

A further object is to provide an improved signal output circuit for electrical musical instruments having means for suppressing the sharp peak curvature of the input wave, and thus rendering the output wave shape of smoother contour to correspond to a more mellow tone quality.

A further object is to provide an improved push-pull oscillator.

A further object is to provide a simple form of electrical musical instrument capable of rendering a melody, with or without octave coupling, which includes but a small number of parts and which may be economically manufactured.

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

Figures 1, 1*a* and 1*b* together constitute a wiring diagram of the instrument;

Figure 2 is a diagram graphically illustrating wave shapes present in some of the generator circuits; and

Figure 3 is a vertical sectional view diagrammatically showing one of the playing keys and switches operated thereby.

General description

In general, the instrument comprises three octaves of keys herein designated 1C to 1B, 2C to 2B, 3C to 3B which are adapted to control the transmission of signals from the generating system to the output amplifier and speaker of the instrument. Each of the keys operates three switches, the first of which renders the amplifier ineffective when two keys of different octave groups are simultaneously depressed, the second of which determines the tuning of the generators to the desired note frequency, and the third of which controls the operation of a relay which connects the generator system to the output amplifier and renders the amplifier effective to amplify and transmit the signal to the speaker.

The generating system comprises a series of cascaded oscillators which are interlocked to generate frequencies at octave intervals, and the frequency of operation of which is determined by a stable master oscillator generating the frequencies of the lowest octave of the instrument.

The system is so arranged that only the master oscillator frequency is controlled by the depression of the playing keys, and this change in frequency is reflected throughout the cascaded frequency doubling stages to provide corresponding changes in their frequencies.

Associated with the master oscillator is a simple vibrato apparatus by which the frequency of oscillation of the master oscillator may be varied throughout a vibrato range at vibrato periodicity, this vibrato means having manually operated controls whereby the degree of its effect may be predetermined. This vibrato frequency shift is reflected, proportionately, in the successive frequency doubling stages.

The instrument is provided with controls operating in a manner similar to those disclosed in the application of Laurens Hammond and John M. Hanert, Serial No. 293,444, filed September 5, 1939, now Patent No. 2,233,258, granted December 31, 1940, whereby the outputs of several stages of the generating system may be combined at will to produce octave coupler effects.

The output circuit of the instrument includes suitable tone control resonant circuits, and also a suitable vacuum tube apparatus for radically changing the relative amplitudes of the harmonics of the tone.

Frequency generating system

As previously stated, the frequency generating system comprises a low frequency master oscillator and a plurality of stages of frequency multipliers which successively double the frequency generated by the master oscillator, thereby to provide the successive octave interval frequencies. The master oscillator comprises a pair of pentodes V1 and V2 which may be of the 6J7G type. These tubes are connected in push-pull arrangement, their cathodes being connected to ground through a self-biasing resistor R1 and their control grids being connected to the ends of the primary winding L1 of an oscillation transformer T1. The center tap of the winding L1 is connected to ground. The inductance of L1 and L2 may be varied, preferably by changing the air gap in the iron laminations to tune the oscillator in the first instance.

The screens of the tubes V1 and V2 are connected to a terminal 300V of the power supply system having a voltage of 300 volts positive with respect to ground, this connection being through a voltage dropping resistor R2. The suppressor grids of the tubes V1 and V2 are connected to their cathodes. The plate of tube V1 is connected through a blocking condenser C1 and a feed-back resistor R3 to the grid of the tube V2. Similarly, the plate of the tube V2 is connected through a blocking condenser C2 and feed-back resistor R4 to the grid of tube V1. Current is supplied to the plates of the tubes V1 and V2 from terminal +300V of the power supply through resistors R5 and R6 respectively.

The push-pull alternating current output of the tubes V1 and V2 is connected, through blocking condensers C3 and C4, across voltage divider resistors R6, R7, R8 and R9 which are connected in series.

Conductors 11 and 12 are connected respectively to the grids of the tubes V1 and V2. As will more fully appear hereinafter, the capacitance between the conductors 11 and 12 is controlled by key operated switches, and thus such capacitance is in effect connected across the ends of the winding L1 of the transformer T1 to form a resonant circuit for substantially determining the frequency of oscillation of the master oscillator tubes V1 and V2.

It will be noted that the plate of the tube V1 feeds energy into the grid of the tube V2, and similarly the plate of the tube V2 is capable of feeding energy into the grid of the tube V1 in opposed phase relation, thus fulfilling one of the conditions necessary for self oscillation.

It will be seen that the circuits are such that increased plate current through the tube V1 results in a lowering of the potential of the grid of tube V2, thus decreasing the plate current through tube V2 and increasing the potential of the plate of said tube. This increased plate potential of the tube V2 results in increased potential of the grid of tube V1, thus further increasing the plate current through the tube V1 until a further increase in grid voltage does not result in increase in plate current through the tube V1. At such time the potential of the grid of the tube V2 begins to drop and a reverse sequence of events takes place. Of course the increase and decrease of plate current through the tube V2 takes place in the same manner but 180° out of phase with respect to the corresponding changes in current through the tube V1, the tubes V1 and V2 thus producing outputs across the resistors R6 to R9 which are substantially 180° out of phase.

Vibrato apparatus

A second winding L2 on the oscillation transformer T1 is provided to vary the inductance of the winding L1 periodically at a vibrato frequency. The means for accomplishing this comprises a vibratory reed 14 which is connected to ground at its fixed end and at its free end carries an iron core 16, the mass of which relative to the stiffness of the reed 14 is such as to cause the latter to have a natural frequency of vibration of approximately 7 C. P. S. The core 16 moves in and out of the field of a coil L3, one terminal of which is grounded and the other terminal of which is connected to a tap 18 of an inductance L4.

A pair of switches 20 and 21 is connected together for simultaneous manual operation, the arrangement being such that the switches are alternately closed in such manner both switches are never closed at the same time. When the switch 20 is closed and the switch 21 open, as the switches are illustrated in full lines in Fig. 1, one terminal of the coil L2 is connected directly to the ungrounded terminal of the coil L3 and the coil L4 is completely disconnected from the circuit so as to have no effect upon the operation. The degree of frequency shift is then dependent upon the change in inductance of L3 as the iron core 16 vibrates in its field. The amount of vibrato of course will also depend upon the number of turns of L2 relative to L1 and to L3.

When the switch 20 is open and the switch 21 closed, as indicated in dotted lines in Fig. 1, the ungrounded terminal of L3 is connected to the tap 18 on L4. The tapped inductance L4 then functions as an autotransformer to reduce the effectiveness of the variable inductance L3 in producing variations in the tuning inductance L1. By so doing, the degree of vibrato is reduced. However, the average inductance (likewise the frequency of the master oscillator), looking out of the winding L2, is the same as for the vibrato "on" position of the switches 20 and 21, because of the added shunt inductance L4. In effect, the shunt inductance of L4, which of course is not variable, compensates for the loss in effectiveness of the variable inductance L3 when the vibrato switches 20 and 21 are turned "off." The position of the tap 18, together with the inductance of L4 determines the degree of residual vibrato present when the switches are in "off" position. It is of course desirable when playing practically all musical selections to have at least a small amount of vibrato present in the tones.

The vibrato reed may be driven through any suitable means, illustrated herein as an electromagnet 22 having one terminal thereof connected to a suitable source of direct current potential indicated as +50V and the other terminal thereof connected to an adjustable flexible contact 24 which is adapted to be contacted by the reed as the latter swings upwardly away from the electromagnet 22. The reed is grounded and a spark suppressing resistor R10 is preferably connected across the contacts. It will be apparent that the reed will be maintained in vibration by the electromagnet in the manner of a vibratory interrupter. The electromagnet 22 is preferably provided with a shading ring to cause the phase of the flux change to lag the closing of the contacts.

When the above described vibrato apparatus is used in conjunction with a high frequency oscillator the core 16 is preferably made of powdered iron so as to reduce core losses.

Frequency doublers

The push-pull output of the master oscillator is supplied through a pair of conductors 25 and 26, the conductor 25 being connected between the resistors R6 and R7, and the conductor 26 being connected between the resistors R8 and R9. The conductor 25 is connected to the grid of a tube V3 through a feed-back winding L5 and a protective resistance R11. Similarly, the conductor 26 is connected to the grid of a tube V4 through a feed-back winding L6 and a protective resistance R12. The tubes V3, V4 are preferably triodes of the 6J5G type. The cathodes of tubes V3 and V4 are connected to ground, and appropriate grid bias is supplied through a terminal 28 of the power supply, this grid bias being applied to the grids of the tubes V3 and V4 through resistors R7 and R8 respectively. The plate current is supplied from a terminal +300V of the power supply through timing resistors R13 and R14 respectively.

The plate of the tube V3 is connected through a timing condenser C5 to one end of the primary winding L7 forming part of a transformer T3, of which the inductance L5 forms a secondary winding. The other end of the primary winding L7 is connected to ground through a relatively large condenser C7 across which a signal voltage is developed, the condenser C7 being shunted by an adjustable potentiometer P1.

Similarly, the plate of the tube V4 is connected to one end of a primary winding L8 through a timing condenser C6, the winding L8 forming part of a transformer T4 of which the winding L6 forms a secondary feed-back winding. The other end of the winding L8 is connected to ground through a relatively large condenser C8 across which a signal voltage is developed, the condenser C8 being shunted by a resistor R16.

The tubes V3 and V4 and associated circuits operate in the manner of two independent relaxation oscillators operating in out of phase relation by 180°, and whose frequencies of relaxation are controlled by tripping signals derived from the master oscillator through the conductors 25 and 26. In operation, current flows through the resistor R13 to charge condenser C5, thus gradually increasing the potential on the plate of the tube V3.

As the condenser C5 becomes charged, current will flow through the winding L7 and condenser C7. This current flow through induction with the winding L5 will cause the potential on the grid of the tube V3 to rise because of phase arrangement of L5 with respect to L7. As the potential on the grid V3 approaches the value at which the tube V3 becomes conducting, a positive trip signal from the master oscillator will be impressed upon the grid of the tube V3 through the circuit including the conductor 25, and this trip signal will, by raising the potential of the grid of the tube V3 to a value at which the tube is conducting, exactly determine the instant at which conduction through the tube commences.

As the tube V3 conducts current, condenser C5 will rapidly become discharged and through the associated winding L7 will induce an opposite current in the winding L5 which will lower the potential on the grid of the tube V3 to a potential at which the tube V3 is cut off, thus completing the relaxation cycle.

The circuit elements associated with the tube V4 are identical in value to the corresponding elements associated with the tube V3 and thus the tube V4 will tend to oscillate at substantially the same natural frequency as the tube V3, the only difference in the natural frequency of oscillation of these two tubes being due to unavoidable irregularities in tube characteristics and in the values of the circuit elements. Since the tripping signal for the tube V4 is derived through the conductor 26, it will be 180° out of phase with respect to the tripping or locking signal supplied through the conductor 25, and as a result, the outputs derived across the signal condensers C7 and C8 will likewise be 180° out of phase.

In order to compensate for differences in tube characteristics of V3 and V4 and other unavoidable differences in the values of circuit constants, the potentiometer P1 is adjusted to such a position that the signal through a decoupling resistor R17 to a junction terminal 30 is made identical in amplitude with the signal derived across the condenser C8 through a decoupling resistor R18. It will thus be apparent that at the junction terminal 30 there will result a signal of generally saw-toothed wave shape of a frequency twice that of the master oscillator, while across the condenser C8 there will be a saw-toothed wave of the same frequency as that of the master oscillator. Thus, a conductor 32 may be connected to the ungrounded terminal of the condenser C8 to provide a signal to be controlled by the key operated switches and other controls hereinafter to be described, while a conductor 34 connected to the junction terminal 30 may similarly be utilized to supply a substantially saw-toothed signal one octave higher than that provided through the conductor 32.

It will be understood that the tubes V3 and V4 together with their associated circuits above described, thus constitute a frequency multiplying, or more specifically a frequency doubling apparatus, for which any other suitable frequency doubling apparatus might be substituted. For example, a full wave rectifier circuit employing either biased or unbiased tubes, a multi-vibrator circuit, a gas tube relaxation oscillator, or similar apparatus might be used. However, the alternately operating relaxation oscillators herein disclosed are preferred since they are not sensitive to changes in the voltages or wave shape of the trip signal throughout a considerable range, and since they produce signals of musically desirable wave shape.

Trip signal distorter

The output of the tubes V3 and V4 constitutes a saw-tooth wave having a very sharp negative peak as represented by the wave A in Fig. 2. This negative peak is caused by the counter E. M. F. offered by the inductances of the transformers T3 and T4. This wave appears at a junction terminal 36 which is connected through decoupling resistors R19 and R20 with the plates of the tubes V3 and V4 respectively.

The signal at the junction 36 is, however, not entirely satisfactory for use as a tripping signal for the next stage of frequency multiplication because of its unsymmetrical character about the vertical axis. In order to render this wave substantially symmetrical, it is transmitted through a non-linear impedance in the form of a triode V5 whose electrodes are operating at low potential. Under these conditions, where a very large signal is applied to the control grid, the plate current will be limited on both the positive and negative swings of the grid voltage which corresponds respectively to the point at which grid current flows and plate current cutoff occurs.

The grid of the tube V5 is connected to the terminal 36 through a blocking condenser C9 and a series grid resistor R21 which functions to limit the grid current on high positive swings of the signal. The grid is connected through the grid resistors R21 and R22 to a negative bias terminal of the power supply system. The cathode of the tube V5 is grounded while the plate, as previously indicated, is connected to a terminal of the power supply of relatively low potential indicated as a terminal +100V of the power supply system. This connection is through a plate resistor R23 in shunt with a primary winding L9 of a coupling transformer T7. The secondary L10 of this transformer is center tapped for push-pull operation of the second stage frequency doubler tubes. The tube V5 may be of the 6J5G type.

Referring to Fig. 2, curve B represents the current wave in the plate circuit of tube V5, while curve A represents the signal voltage at terminal 36. From these curves it is seen that the plate current reaches a value at which grid current commences flowing at a very small percentage of the total positive swing of signal voltage, and that an increase of positive signal voltage above this value produces a negligible increase in plate current. Also, the plate current wave B reaches a flat portion corresponding to the plate current cutoff of the tube, which occurs at a very small percentage of the total height of the negative grid swing. By making the signal voltage amplitude many times the total amplitude permissible when operating over the relatively linear portion of the grid characteristic of the tube V5, an output which is substantially flat both on the positive and negative swings of the signal voltage is obtained. The plate current is substantially symmetrical about the vertical axis. This symmetry about the vertical axis is desirable for tripping the frequency multiplier tubes of the following stage in substantially 180° phase relation. This effect is improved by employing a low plate potential on tube V5, such as +100V indicated.

The second stage frequency multiplier is identical with the first stage previously described except that the values of the various circuit elements such as R13, R14, C7, C8 and the transformer T3 are chosen such that the second stage relaxation oscillators tend to relax at a rate approximately twice that of the first stage frequency doubling relaxation oscillators. The signal is derived from the second stage frequency doubler through a conductor 38.

Similarly, the third and fourth stages of frequency multiplication are identical in circuit arrangement with the first stage (but having elements of suitably different values), and the tripping signal distorters between these stages are likewise similar in circuit arrangement to that between the first and second stages. The fifth stage differs slightly from the previous stages in the circuit arrangement in that the load offered by resistors R19 and R20 in the corresponding first frequency multiplication stage is absent, resulting in slightly lowered values for the timing resistors R13 and R14 than would otherwise be required. The signals from the third, fourth, and fifth stages are derived through conductors 40, 42 and 44 respectively.

It will thus be seen that the generating system comprises a low frequency master oscillator which is tunable over an octave range, and which transmits a tripping signal to a first stage of frequency multiplication. Each of the stages of multiplication successively multiplies the frequency by a factor of two, so that six frequencies of successive octave intervals are provided. It will be understood that a change in the frequency of the master oscillator from one note to another note in its octave range is reflected throughout the frequency multiplier stages so that the frequencies generated by the latter vary proportionately with the changes in frequency of the master oscillator.

Register controlling apparatus

It is desirable in a melody type instrument to provide means whereby the outputs of a plurality of stages may be combined upon the depression of a playing key so as to produce octave coupling effects. To accomplish this purpose there are provided a plurality of control tablets 46, 47, 48, 49, each adapted upon operation to close three switches 46*a*, 46*b*, 46*c*, 47*a*, 47*b*, 47*c*, etc. The switches 46*a*, 47*a*, 48*a*, and 49*a* are adapted to connect conductors 32, 34, 38 and 40 respectively to a bus bar 50 associated with the lowermost octave of keys, each through a decoupling resistor R24. Similarly, the conductors 34, 38, 40 and 42 are adapted to be connected by switches 46*b*, 47*b*, 48*b* and 49*b* respectively with a middle octave bus bar 52, each through a decoupling resistor R24. In the same manner conductors 38, 40, 42 and 44 are adapted to be connected by switches 46*c*, 47*c*, 48*c*, and 49*c* respectively with a high octave bus bar 54, each through a decoupling resistor R24.

Each of the bus bars 50, 52, 54 is grounded through a resistor R25 which may be of approximately the same value as the resistor R24. The impedance of each of the frequency generators is made low, in the order of 5000 ohms, and assuming this value is the generator impedance, the resistors R24 and R25 may have a value in the order of 50,000 ohms to effect substantial decoupling between the various generators when a plurality of the tablets 46—49 are simultaneously operated.

The resistances R25 serve as a load resistor to decrease the amplitude of the signal operating upon the associated bus bar 50, 52 or 54 when a plurality of the tablets 46—49 are simultaneously operated, so that the peak amplitudes of the signals on these bus bars remain approximately the same, regardless of the number of tablets 46—49 which are simultaneously operated. In this way the full power output of the instrument as a whole may be advantageously used on any combination of tablets 46—49 without danger of overloading the amplifier and speaker.

The bus bars 50, 52, and 54 lead to relay operated switches 50*a*, 52*a* and 54*a* respectively and are normally in the position shown in the drawings, so as to connect the bus bars 50, 52 and 54 to ground. By connecting these bus bars to ground, the outputs of the various stages through decoupling resistor R24 are grounded, and thus are prevented from undesired coupling through their high impedance series paths with other generators connected to the same bus bar. This coupling condition would otherwise prevail when more than one of the register control tablets 46—49 are operated.

The control tablets 46—49 may bear appropriate indicia, such as "Bass," "Tenor," "Contralto," and "Soprano" respectively, to indicate the pitch registers determined thereby.

As previously indicated, and as will appear more fully hereinafter, there are three octaves of keys, and depression of any key in the lower octave will result in energization of a relay winding 56. Similarly, depression of any key in the middle octave will result in the energization of the relay winding 57, while depression of any key in the highest octave will result in energization of the relay winding 58. These relays are for the purpose of connecting the outputs of the generators to the grid of a pre-amplifier tube V6.

It will be noted that energization of the relay winding 56 will result in the disconnection of the bus bar 50 from ground, and through the switch 50a connect this bus bar to the grid of the tube V6. Similarly, energization of the relay winding 57 will result in disconnecting the bus bar 52 from ground and connecting it through a resistor R26 to the grid of the tube V6. Energization of the relay winding 58 will disconnect the bus bar 54 from ground and connect it through a resistor R27 and the resistor R26, which is in series with R27, to the grid of the tube V6.

The signal voltage on the grid of the tube V6 is determined not only by the signal on bus bars 50, 52 and 54, but also upon the voltage divider effect of resistors R26 and R27 in relation to a grid resistor R28 associated with the preamplifier tube V6. The resistors R26 and R27 preferably are of high impedances in the order of 350,000 ohms and 400,000 ohms respectively, while the resistor R28 may be in the order of 1 megohm. As a result, it will be apparent that a signal on bus bar 50, when connected to the grid of amplifier tube V6 by contact switch 50a is substantially unaffected by the grid resistor R28, whereas signals on the bus bar 52 will be reduced substantially in a ratio of the value of voltage divider resistors R28 and R26.

A signal developed on bus bar 54 will be reduced to an extent determined by the values of the resistors R26 and R27, as compared with the value of resistor R28. This signal reduction is desirable because the saw-tooth signal as developed at any of the generator conductors 32, 34, 38, 40, 42 or 44 progressively increases in amplitude as the frequency of the master oscillator is tuned lower. Compensation is then made for this increase in amplitude when changing from one octave group of playing keys to another. Thus, in playing adjacent semi-tones in different octave groups, the amplitudes of the signals impressed upon the preamplifier tube V6 will be substantially equalized. It will be noted that by making the resistors R26, R27 and R28 high with respect to the values of the decoupling resistor R24, this same equalization is effected even though a plurality of tablets 46—49 are operated at the same time.

Key switch circuits

As shown in Fig. 1, there are three octaves of keys, the octaves being designated the "low," "middle" and "high" octaves. The keys of the "low" octave are designated 1C to 1B, the keys of the "middle" octave are designated 2C to 2B, and the keys of the "high" octave are designated 3C to 3B. Each of the keys, with the exception of the keys 1C, 2C and 3C, sequentially operates three switches, the excepted keys operating only two switches. For example, the switches for the key 1D bear the reference characters 1D1, 1D2, 1D3 and are operated in this order, the switch 1D1 being closed, the switch 1D2 being opened, and the switch 1D3 being closed upon depression of the key 1D.

The first closed switches, of which the switch 1D1 is representative, are connected in octave groups through conductors 61, 62 and 63 respectively, and upon operation of the associated keys are adapted to make contact with a grounded bus bar 64. The conductors 61, 62 and 63 are connected to a common conductor 66 through resistors R31, R32 and R33 respectively, and are for the purpose of rendering the amplifier ineffective whenever two keys in different octave groups are simultaneously depressed. This means is more fully disclosed and claimed in my co-pending application Serial No. 303,728, filed November 10, 1939, and will be further referred to hereinafter in connection with the description of the operation of the instrument.

As shown in Fig. 1, there are twelve tuning condensers designated C10 to C21 inclusive. Each of these condensers has one terminal thereof connected to the conductor 12. The condenser C10 has its other terminal connected to the conductor 11. It will be recalled that the conductors 11 and 12 are connected to the ends of the tuning inductance L1 of the master oscillator.

When all of the switches of the groups including 1D2, 2D2 and 3D2 are closed, all of the condensers C10 to C21 are in parallel across the conductors 11 and 12, and the master oscillator will oscillate at a frequency corresponding to the note C, for example, 65,406 C. P. S.

It will be noted that corresponding switches 1D2, 2D2, 3D2 etc. of the "low," "middle" and "high" octave groups are connected in series between terminals of the condensers C19 and C20, and that all of the similar group of switches (such as 1E1, 2E1, and 3E1) are connected in series with each other and successively across condensers C10 to C21. Thus, for example, if the switch 1D2 or the switches 2D2 or 3D2) is opened, the condensers C10 to C19 will remain connected across the conductors 11 and 12, while only the condensers C20 and C21 are disconnected from these conductors. By having this series arrangement of second operated switches, and hence the parallel arrangement of the condensers C10 to C21, these may be of relatively small size. This is a factor of some importance in the cost of an instrument of this type where the master oscillator oscillates at low frequencies and would require relatively large condensers for its tuning if the condensers were connected in series, as shown, for example, in my prior application, Serial No. 274,325, filed May 18, 1939.

Since the condensers C10 through C21 are permanently connected across the conductors 11 and 12 when no key is depressed, all generators will operate at their "C" note frequencies, and it is therefore unnecessary to provide tuning switches for the keys 1C, 2C and 3C.

The third switch such as 1C3 to 1B3, 2C3, etc. is the last switch to be closed upon depression of its associated key, one contact of each of these switches of the "low" octave being connected to a conductor 71, one contact of each of these switches of the "middle" octave being connected to a conductor 72, and corresponding switch contacts for the "high" octave being connected to conductor 73. These switch contacts are adapted to engage a common bus bar 74 which is connected to ground.

The conductors 71, 72 and 73 are respectively connected to the relay windings 56, 57 and 58, the power circuit through these relay windings being completed through a common series resistor R34 which connects to a junction terminal 74. Current is supplied to the junction point 74 through a voltage divider circuit comprising resistors R35 and R36 connected between a terminal +400V of the power supply system and ground. A relatively large condenser C24 is connected between the terminal 74 and ground.

Signal transmission, signal quality and signal amplitude control

The terminal 74 is connected to the cathodes of a pair of push-pull control tubes V7 and V8 which are preferably remote cut-off pentodes such as the 6K7G type. It will be seen that upon depression of any playing key that the resistance of the energized relay winding plus the common series resistance R34 is put in shunt to ground with resistor R36 of the voltage divider R35—R36, thus reducing the potential at the junction terminal 74. This reduction in the potential of the cathodes of control tubes V7 and V8 results in a corresponding decrease in the effective bias on the control grids of these tubes. This change in the cathode potential of the tubes V7 and V8 results in the removal of the cutoff bias which normally existed at the terminal 74 before the key was depressed, and thus renders these tubes capable of conducting the signal to the power amplifier and speaker. Upon release of the depressed playing key and the opening of its corresponding switch, such as 1C3, 3B3, etc., the voltage at the terminal 74 will gradually rise to the normal potential, at which the tubes V7 and V8 are cut off, until terminal 74 attains the potential determined by the voltage divider resistors R35 and R36. The rate of change of potential is rendered gradual so as to eliminate the possibility of keying transients by virtue of the fact that the condenser C24 is connected between the junction terminal 74 and ground, and thus limits the rate of change of potential at this terminal.

As previously described, the signals from the selected stages of the frequency generating system are impressed upon the grid of the preamplifier tube V6 when one of the relay windings 56, 57, or 58 is energized. The preamplifier tube V6 is preferably a triode of the 6F5G type, and is shown as being self-biased and supplied with plate current through a load resistor R37 connected to a terminal +300V of the power supply system. The alternating signal from the plate circuit of the tube V6 is transmitted through a blocking condenser C25 and through a decoupling resistor R38 to the grid of the tube V9. The tube V9 is preferably a remote cutoff pentode of the 6K7G type, and is operated non-linearly with a very large signal on its control grid. The screen voltage to this tube is derived from a +300V terminal of the power supply system through a voltage dropping resistor R39. A condenser C26 prevents screen degeneration and is connected between the screen and ground.

A grid resistor R40 is connected between the control grid and cathode, and a grid condenser C27 is likewise connected between the control grid and cathode of the tube V9. Condenser C27 functions both to round off the sharp positive peak of the high amplitude input signal and to accumulate bias for the operation of tube V9 on positive pulses which drive the grid to the point at which the grid current would otherwise commence to flow.

Plate voltage is supplied from a +300V terminal on the power supply system through a load resistor R41, the output being blocked by condenser C28 and a resistor R42 which functions as a current limiting impedance to suppress very low frequencies. A switch 76 is connected between the input and output terminals of the tube V9 and constitutes a tone quality control which may be operated at will by the musician. The opening of this switch renders the tube V9 effective to materially decrease the amplitudes of the higher harmonic partials present in the output signal of the tube V6. It will be recalled that the signals supplied by the generating system are generally of saw-tooth character, and thus include the higher harmonics in considerable amplitude.

Due to the fact that a very large signal is applied to the control grid of tube V9, the tube will operate non-linearly and the saw-tooth wave is of such phase that the retrace curvature of the saw-tooth (which is a very nearly vertical line), will operate in a negative direction on the control grid characteristics of tube V9. Thus, as the input signal to the grid of V9 suddenly becomes very negative, the remote cutoff characteristics of the tube V9 will round off this sharp negative peak and thus alter the output wave to a rounded contour rather than the extremely sharp saw-tooth retrace curvature impressed on its input.

The tone quality of the output is dependent not only upon the quality of the input signal but also upon the curvature of the remote cutoff grid characteristic. Thus, by introducing this tube, the harmonic series of the output corresponds to a more mellow tone than the harmonic series of its input. It is to be noted that this reduction in harmonic content and total alteration of the harmonic series, which will be further modified as disclosed hereinafter by the tone control networks, is made possible without the use of electrical filter networks which emphasize low frequencies. As a practical matter this is of considerable importance because an inductance-capacity resistance network capable of altering the saw-tooth tone quality to the extent which is accomplished by the mute tube V9 would be extremely complicated, and would emphasize any spurious low frequency noises to a marked degree. Such spurious low frequencies are not present in the output circuit of the tube V9. The mellowing effect of the mute tube V9 is substantially independent of the signal frequency because it is determined nearly wholly by the geometrical parameters of the remote cut-off tubes, which are not frequency discriminative.

Whenever the mute effect is not desired, the switch 76 may be closed and the output of the preamplifier tube V9 thus by-passed to the tone control networks. These networks include a plurality of normally closed series connected switches 78 to 82, each of which when opened (by the player during the course of playing a musical selection), connects the output of the preamplifier tube V6, as modified, when desired, by the mute tube V9, to ground through resonant filtering meshes of different frequency response characteristics, each mesh including either an inductance, a capacitance, or a resistance, or combinations of these elements in parallel.

The output of the preamplifier tube V6, whether or not modified by the mute tube V9, also flows through a primary winding L11 forming part of an audio transformer T5. The secondary L12 of the transformer T5 has its terminals connected respectively to the grids of the control tubes V7 and V8.

The mid-point 83 on the winding L12 which forms the grid return and the point at which biasing potential is applied, is connected to a volume control apparatus which is adapted to be operated by the player to control the degree of amplification of the tube V7 and V8. This volume control apparatus comprises a potentiometer in the form of a plurality of resistors R43 of graduated value, which are adapted to be successively connected to a conductor 84. The conductor 84 is connected to a terminal +100V of the power supply system, and is adapted to be operated by a swell pedal or other suitable hand, knee or foot operated controls.

The resistors R43 each have one end thereof connected to a junction terminal 86 which is connected to a terminal +150V of the power supply system through a resistor R44. The resistors R43 which are connected in circuit by operation of the volume control, together with the resistance R44, form a voltage dividing network which determines the potential upon the junction point 86. This junction point 86 is connected to the mid-point 83 of the secondary winding L12 through a large decoupling resistor R45, the mid-point 83 of the secondary winding L12 being connected to ground through a condenser C29 which serves as a means to prevent sudden changes in biasing potential, and thus prevents undesirably abrupt changes in the volume of the tones produced as the volume control is operated.

When it is desired to have the tones sound with a slow attack, a switch 88 is closed, thereby connecting a condenser C30 between the terminals 83 and 74. The function of this condenser C30 is to temporarily maintain the control grids of V7 and V8 at a cutoff point when any one of the relays 56, 57, or 58 is operated. After a short interval of time (determined in part by the size of condenser C30), the potential upon the junction point 83 will attain a value determined by the volume control network. This imparts slow attack to the tones. When the switch 88 is open, the condenser C30 is of course ineffective to produce this result.

It will be recalled that whenever any of the playing keys is depressed, the conductor 66 is connected to ground through one of the resistors R31, R32 or R33. The conductor 66 is connected to the suppressor grids of tubes V7 and V8, and is also connected to a terminal +400V of the power supply system through a voltage divider resistor R45. A condenser C31 is connected between the conductor 66 and ground so as to prevent sudden changes in potential on the conductor 66.

The values of the resistors R31, R32 and R33 are such with respect to the value of the resistor R45 that when any key or keys in only one octave group of keys is depressed, the potential on the suppressor grids of the tubes V7 and V8 will be lowered to a proper operating value. When, however, keys in two or more octave groups are simultaneously depressed, two or more of the resistors R31, R32 and R33 will be connected in parallel to ground, and as a result, their combined resistance will be divided by two or three as compared with the resistances when keys in but one octave group are depressed. Under these conditions, the potential on the suppressor grids of the tubes V7 and V8 will drop to a value beyond plate current cutoff, the condenser 31 serving to render this cutoff smooth and without a noticeable transient.

The screens of the tubes V7 and V8 are connected to a terminal +250V of the power supply system, while the plates thereof are connected to a terminal +400V of the power supply system respectively through the load resistors R47 and R48. Blocking condensers C33 and C34 are provided for the output circuits of the tubes V7 and V8, and transmit signals to the grids of power amplifier tubes V11 and V12 respectively.

The power tubes V11 and V12 are preferably pentodes, for example of the 6F6G type. The grids of tubes V11 and V12 are self-biased through cathode resistor R49 and are connected to ground through grid resistors R51 and R52. The power output tubes V11 and V12 are connected to the terminals of the primary winding L13 of output transformer T6, the latter being provided with a center tap connected to a +300V terminal on the power supply system. The screens of tubes V11 and V12 are also connected to the +300V terminal through a voltage dropping resistor R53. A secondary winding L14 of transformer T6 is connected to the voice coil of a loud speaker 90.

Operation

The operation of the individual portions of the circuits employed has been set forth in connection with the detailed description of the circuits, so that it is necessary to review only generally the method of operation of the instrument as a whole.

The instrument is played in the manner of any melody instrument, that is, the player intentionally depresses only one key at a time although in the course of playing, especially legato, he may depress two keys simultaneously, in passing from one to another. When two keys in the same octave group are simultaneously depressed, the higher pitch key will control the sounding of the signal because of the series arrangement of the second operated switches. If, however, two keys of different octave groups are simultaneously depressed, their first operated switches, namely, switches corresponding to the switches ID1, will result in completing circuits through two of the resistors R31, R32 and R33 in parallel to ground, thus applying cutoff bias to the suppressor grids of the control tubes V7 and V8. There can be no condition when the instrument will produce tones of spurious pitch tones because whenever the keys are depressed in a manner which would otherwise produce tones of such spurious pitch, the output of the instrument is cut off at the control tubes before the second operated key switch is effective to change the pitch of the generating system.

The register controls 46—49 are pre-selected by the musician to pitch the tones of the instrument in the desired musical register. For instance, the operation of control 46 will cause production of tones in the bass voice range, operation of 47 will cause production of tones in the tenor voice range, 48 in the contralto voice range, and 49 in the soprano voice range. Thus, the playing keys do not have any inherent pitch, but the pitches of the tones produced upon the operation of the keys is dependent upon the register controls which are selectively operated by the player. By employing three octaves of keys, however, it is possible to play practically any melody without having to make any changes in the register control switches 46—49. Thus, the three octave keyboard can produce tones covering a six octave range whose lowest fundamental frequency, the note C1, is 65.406 C. P. S., and the highest fundamental frequency, the note B6, is 3951.07 C. P. S.

In many cases the musician will operate more than one of the controls 46—49 to produce a chorus of octave tonalities similar to the effect produced by octave coupler stops of organs. Also, he will selectively operate the desired tone quality controls 78—82 by opening one or more of the switches 78—82. Likewise he may open switch 76 which will render the mute tube circuit operative to introduce a new harmonic series. It is to be noted that when the mute switch 76 is closed, one series of tone qualities may be obtained by the proper operation of the switches 78—82, while when the mute switch 76 is open an entirely different series of tone qualities may be obtained by the operation of these switches 78—82.

The volume of the instrument may be adjusted preferably by a knee or foot operated control to vary the over-all acoustic output of the instrument, and the rate of attack of individual tones may be adjusted by opening or closing the switch 88. In addition, the player may introduce the vibrato effect at will by operation of the switches 20—21.

The instrument has excellent frequency stability, but because it frequently will be played with other instruments whose tuning varies, as with humidity and temperature, an adjustable tuning control is provided which varies the inductance of the oscillation transformer T1, and thus varies the frequency of the master oscillator. By varying this single inductance, all of the tones of the even tempered scale may be made sharp or flat without impairing their octave frequency relations and their temperament.

While each stage frequency multiplier may vary in frequency generally throughout a wide range, of as much as two or three octaves, nevertheless their frequencies of relaxation are always controlled by the trip signal supplied by the preceding stage.

The keyboard of the instrument may be of the type adapted to be attached to a piano in a manner such as that disclosed in the patent to Laurens Hammond No. 2,203,459, and a similar type of tone cabinet may be employed, or if desired, the keyboard and tone cabinet may be combined in a unitary structure. When the keyboard is secured to the front rail of a piano, the musician may play the melody part on the electric melody instrument with the piano, and play the accompaniment upon the piano.

Because of the fact that sustained tones may be produced by the melody instrument, musically interesting and useful results may be obtained by playing upon both instruments simultaneously.

While I have shown and described a particular embodiment of my invention it will be apparent to those skilled in the art that numerous modifications and variations may be made in the form and construction thereof, without departing from the more fundamental principles of the invention. I therefore desire, by the following claims, to include within the scope of my invention all such similar and modified forms of the apparatus disclosed, by which substantially the results of the invention may be obtained by substantially the same or equivalent means.

I claim:

1. In an electric musical instrument having an output circuit including an electroacoustic translating means, the combination of a plurality of playing keys, a massive oscillator, circuits completed by operation of said keys respectively for tuning said master oscillator to any one of the semi-tone frequencies of an octave, a first stage push-pull frequency doubler having its frequency controlled by said master oscillator, a plurality of additional frequency doublers, means for coupling said additional frequency doublers to said first stage frequency doubler in cascaded relation, and means controlled by operation of said keys for causing the transmission of a signal from said frequency doubler stages to the output circuit of the instrument.

2. In an electrical musical instrument having a gamut of a plurality of octaves, the combination of a plurality of octaves of playing keys, a master oscillator having its frequency of oscillation controlled by said keys, a plurality of frequency doublers connected in cascade so as to provide signals the frequencies of which are in octave relationship, means to stabilize the frequency of the lowest frequency doubler by signals derived from said master oscillator, and means for coupling the remaining frequency doublers in cascade to said lowest frequency doubler, whereby the frequency of operation of all of said frequency doubler stages will be controlled by the frequency of oscillation of said master oscillator.

3. In an electric musical instrument, the combination of a low frequency oscillator, a plurality of push-pull frequency doubling stages, means to couple said oscillator to the first of said frequency doubling stages, and means for coupling said frequency doubling stages in cascade, said last named means including a non-linear trip signal distorting mesh.

4. In an electrical musical instrument, a push-pull frequency doubler generating a generally saw-tooth output wave, a second push-pull frequency doubler, and means to couple said first frequency doubler to said second frequency doubler to cause said first doubler to control the frequency of operation of said second doubler, said coupling means comprising an electron discharge device having an input and an output circuit, said input circuit being connected to receive the output signal of said first doubler, and the output circuit of said device being connected to transmit a trip signal to control the frequency of operation of said second doubler, said device operating to limit the amplitude of its output signal to a value much lower than the amplitude of the input signal thereof, whereby the output signal wave form of said device will be substantially symmetrical about the vertical axis despite lack of such symmetry in the signal supplied to the input circuit of said device.

5. In an electrical musical instrument having an output circuit including electroacoustic translating means, the combination of a plurality of octaves of playing keys, a master oscillator having a tuning circuit including an inductive reactance and a plurality of condensers, each having one terminal connected to a common conductor, and a switch operated by each of said playing keys, all of said switches being connected in series, with the switches associated with corresponding keys of the different octaves connected in groups across the other terminals of adjacent condensers.

6. In an electrical musical instrument, the combination of an oscillator including an inductance and a plurality of condensers forming a tuning resonant mesh determinative of the frequency of oscillation of said oscillator, said condensers each having one terminal connected to a common conductor, a plurality of octaves of playing keys, a switch operated by each of said keys, all of said switches being connected in series and being arranged in groups, each group consisting of the switches associated with the keys

of corresponding notes in the different octaves, and each group being connected across the other terminals of two of said condensers.

7. In an electrical musical instrument including an amplifier and a cascaded series of frequency generating devices operating at octave interval frequencies, the combination of a plurality of octaves of playing keys, a first switch operated by each of said keys to render said amplifier ineffective when two or more keys located in different octave groups are simultaneously depressed, a second switch operated by each of said keys and effective to determine the frequencies supplied by said generators, a relay for each octave of keys, a third switch associated with each of said keys for controlling the energization of its associated relay, and means operated by said relay to connect the outputs of selected generators to said amplifier.

8. In an electrical musical instrument having an amplifier and a frequency generating system including a master oscillator and a plurality of electron discharge devices having their frequencies of operation stabilized by said master oscillator and arranged to supply signals of frequencies which bear higher octave relationships to the frequency generated by said master oscillator, the combination of selectively operable means for conditioning the connection of the outputs of said frequency doublers to said amplifier, means controlled by said keys for connecting said selected outputs to said amplifier, and a mute control tube receiving a signal from said amplifier and operable to alter the wave shape thereof, thereby to change the effective harmonic pattern of the signal produced.

9. In an electrical musical instrument in which generators of different frequencies are provided to supply output signals of generally saw-tooth wave shape, a remote cutoff mute tube having its input connected to receive signals from said generators, said mute tube being effective to alter the wave shape of the signal received thereby substantially independently of the frequency, whereby the variation in tone quality of the signals produced by said mute tube will be substantially independent of the frequency of the signal.

10. In an electrical musical instrument, the combination of an electron discharge device having a cathode, plate, and a remote cutoff grid, an input circuit for said device, an output circuit for said device, means connected to said output circuit for amplifying the output of the device and translating it into sound, and means to supply to said input circuit a signal wave having relatively rapid changes in curvature and of amplitude sufficient to operate over the major portion of the grid characteristic curve of said device, whereby the signal wave in the output circuit of said device will have more gradual changes in curvature than are present in the input wave, and will operate so as to have the amplitude of its output signal change to a negligible extent with changes in the amplitude of its input signal.

11. In an electrical musical instrument, the combination of an electron discharge device having a cathode, plate, and a remote cutoff grid, an input circuit for said device, an output circuit for said device, means connected to said output circuit for amplifying the output of the device and translating it into sound, means to supply to said input circuit a signal wave having relatively rapid changes in curvature and of amplitude sufficient to operate over the major portion of the grid characteristic curve of said device, and a condenser connected across the input circuit of said device, said condenser being of sufficient capacitance to decrease curvature of the positive peak of the input signal wave, whereby the signal wave in the output circuit of said device will have more gradual changes in curvature than are present in the input wave, and will operate so as to have the amplitude of its output signal change to a negligible extent with changes in the amplitude of its input signal.

12. In an electrical musical instrument having an output circuit including electroacoustic translating means, a plurality of sources of electrical impulses maintained at octave interval frequencies, each of said sources having a pair of output terminals one of which is grounded, a plurality of bus bars, means including individual switches and individual decoupling resistors for selectively connecting the ungrounded terminals of said sources to said bus bars, load resistors respectively connecting said bus bars to ground, normally closed switches connecting said bus bars to ground, and key controlled means for opening said last named switches and connecting said bus bars to the output circuit of the instrument.

13. In an electrical musical instrument having an output circuit including electroacoustic translating means, a plurality of sources of electrical impulses maintained at octave interval frequencies, each of said sources having a pair of output terminals one of which is grounded, a plurality of bus bars, means including individual switches and individual decoupling resistors for selectively connecting the ungrounded terminals of said sources to said bus bars, load resistors respectively connecting said bus bars to ground, normally closed switches connecting said bus bars to ground, a voltage divider network having a plurality of terminals and determining the effective impedance looking into the output circuit of the instrument, and key controlled means for opening said normally closed switches and connecting said bus bars to different terminals of said network, thereby to compensate for variations in the amplitudes of the signals on said bus bars with variations in the frequencies of said sources.

14. The combination set forth in claim 12 in which the impedances of said decoupling resistors are each in the order of ten times as great as the impedances of each of said sources, and in which the effective impedance looking into the output circuit of the instrument is in the order of twenty to forty times the impedance of each of said decoupling resistors.

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