Sept. 2, 1941. J. M. HANERT 2,254,284

ELECTRICAL MUSICAL INSTRUMENT

Filed May 18, 1939 4 Sheets-Sheet 1

Fig. 1

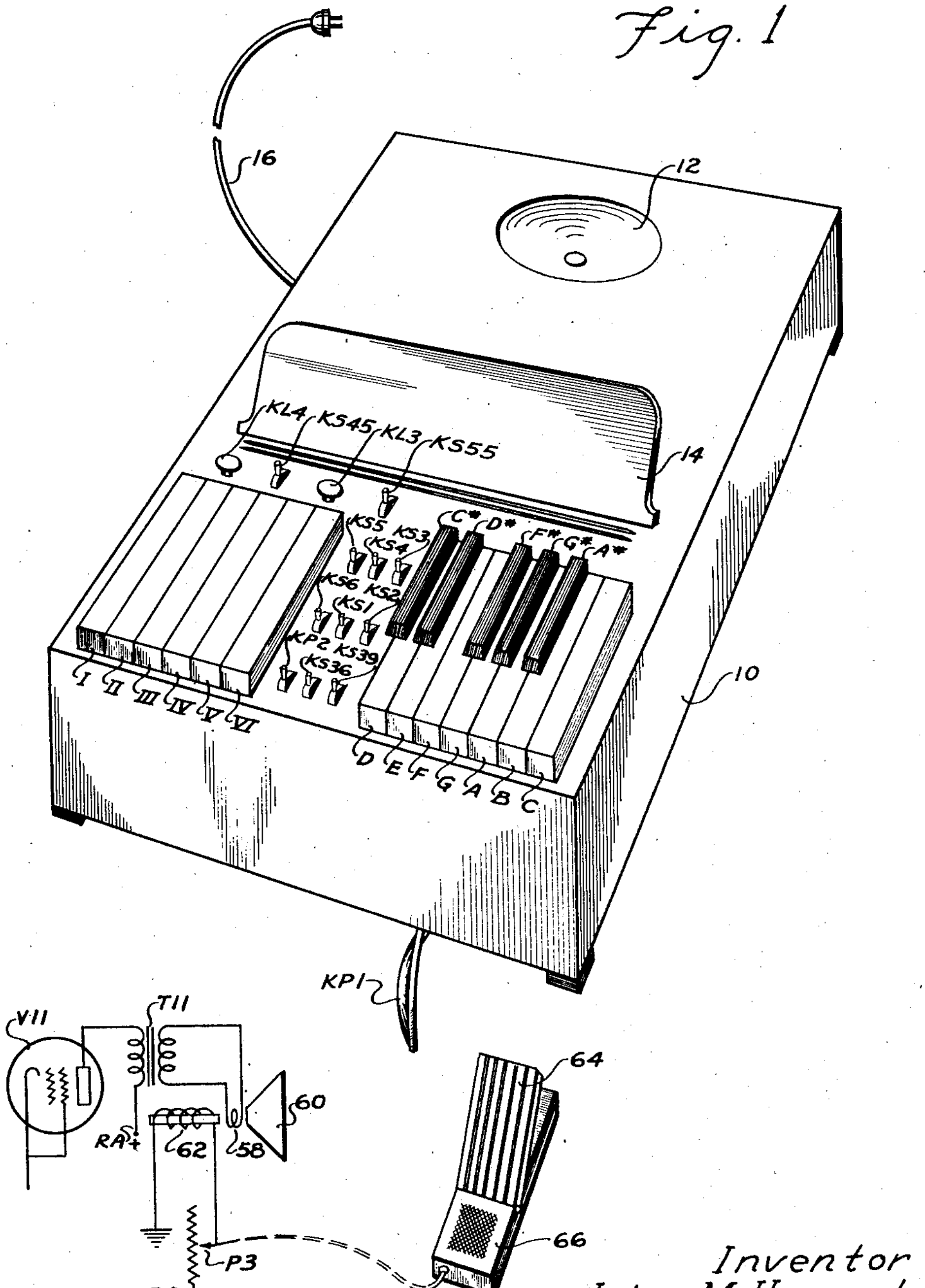

Fig. 5

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ELECTRICAL MUSICAL INSTRUMENT

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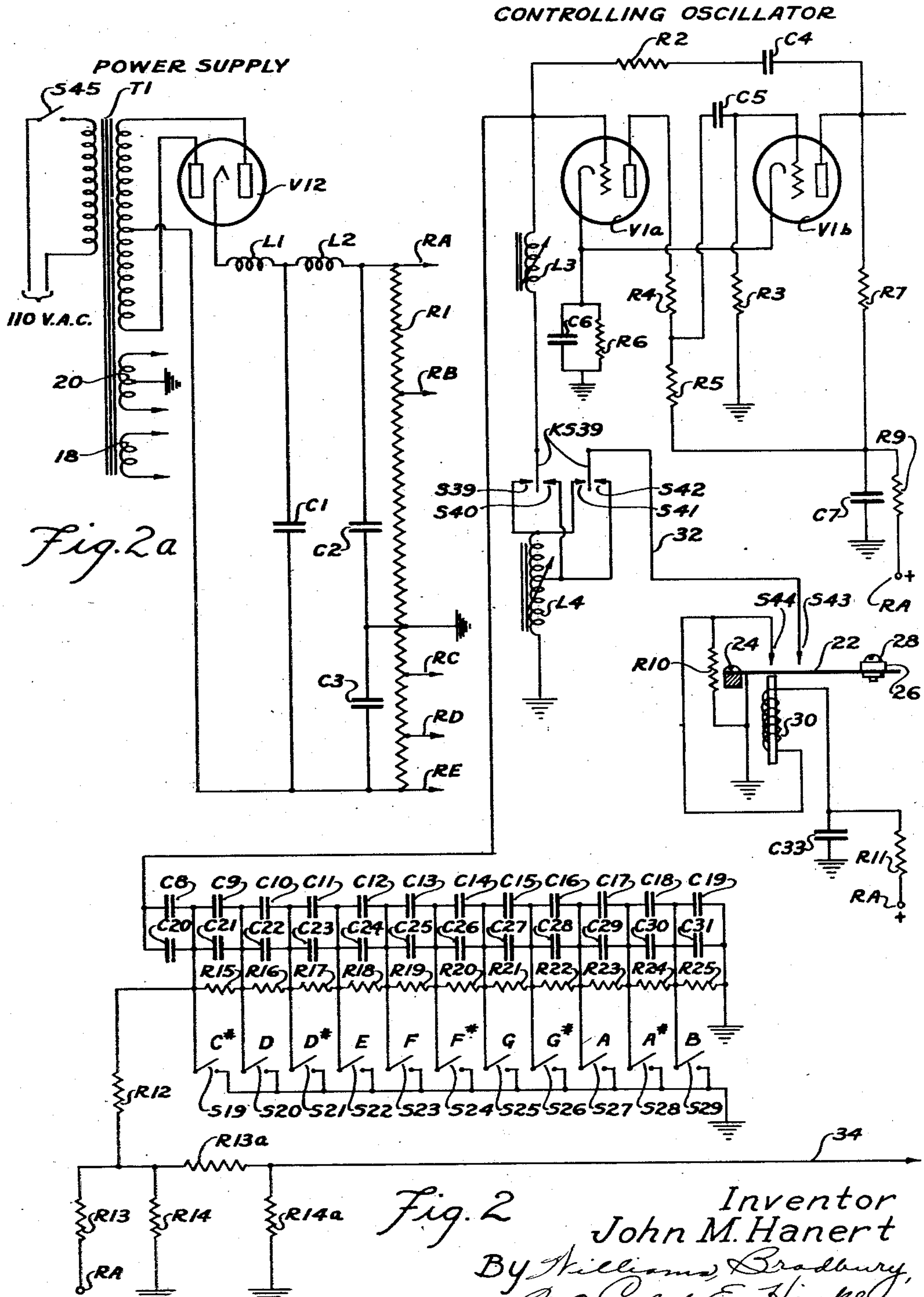

Fig. 2a

Fig. 2

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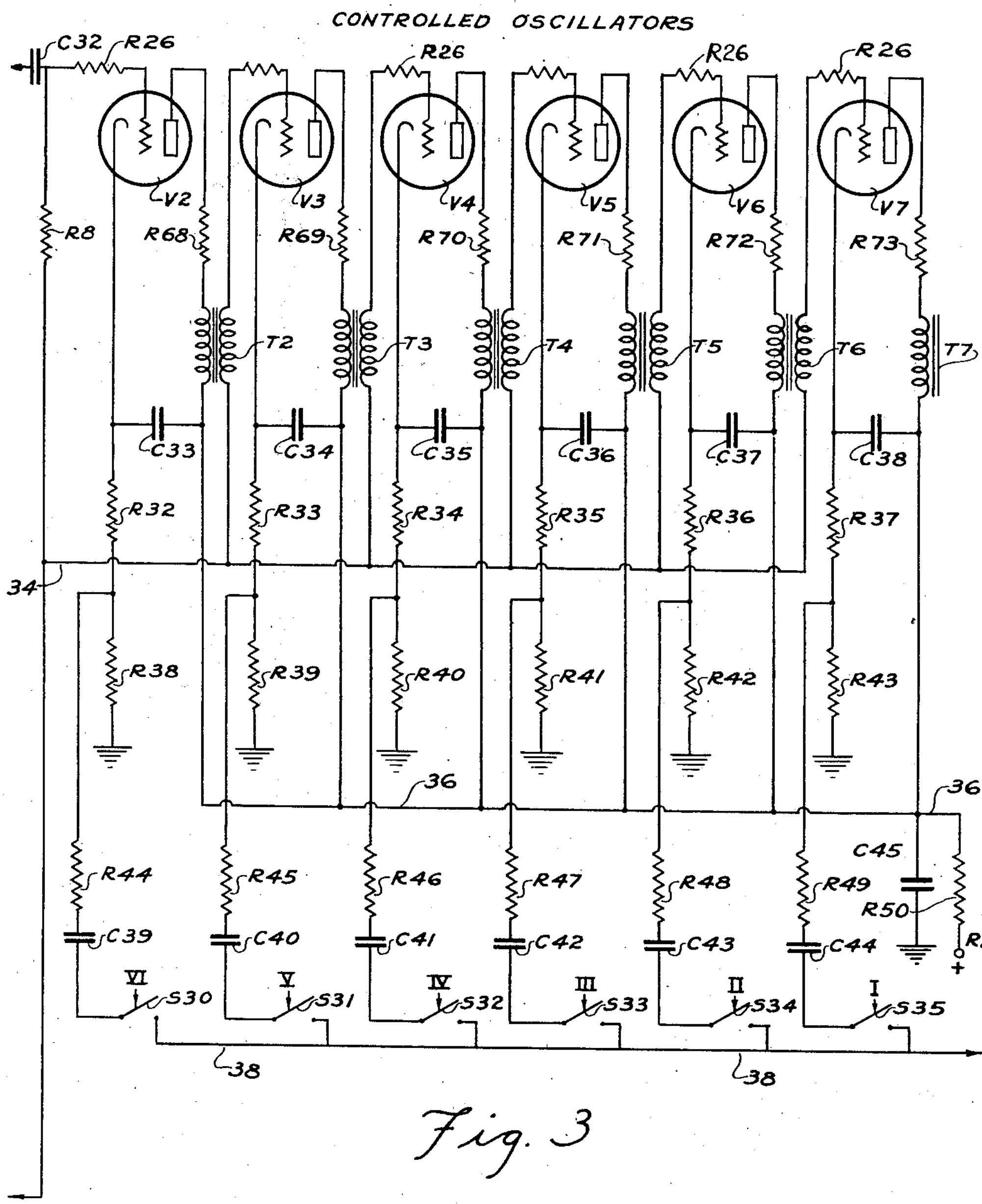

Fig. 3

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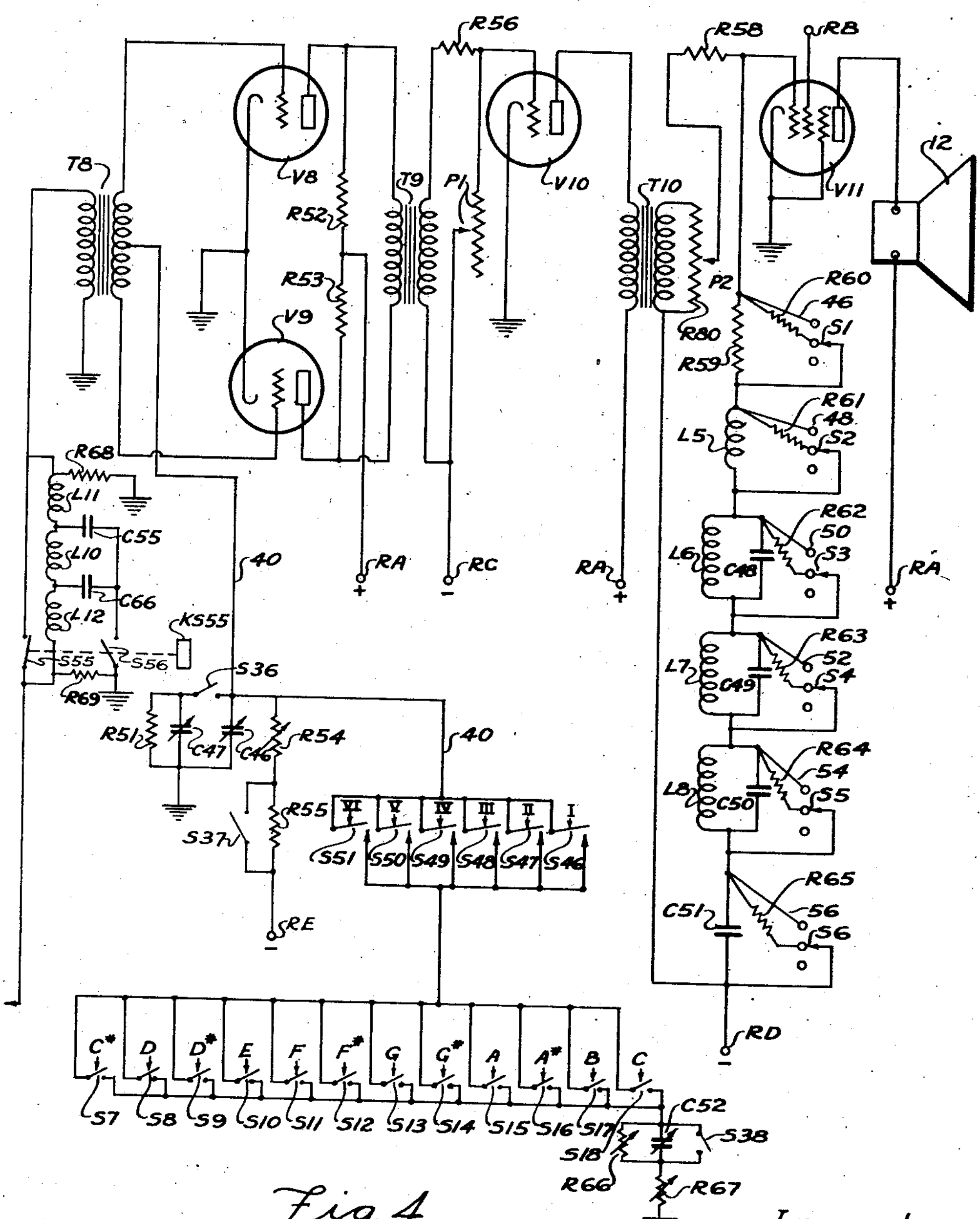

Fig. 4

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Patented Sept. 2, 1941

2,254,284

UNITED STATES PATENT OFFICE

2,254,284

ELECTRICAL MUSICAL INSTRUMENT

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Application May 18, 1939, Serial No. 274,325

31 Claims. (Cl. 84—1.19)

My invention relates generally to electrical musical instruments, and more particularly to instruments of this type in which the tone signal is electrically generated and its transmission to an electroacoustic translating means controlled by means of keys and the like.

It is the primary object of my invention to provide an electrical musical instrument which is capable of producing a wide variety of tone colors and effects, but which is nevertheless of very simple construction, and may be economically manufactured for sale at a relatively low price.

A further object is to provide an improved electrical tone signal generating system employing interlocked oscillators for frequency stabilization, and having means whereby the frequency of oscillation of the oscillators may be readily and accurately controlled so as to make it possible for each of the oscillators to generate signal frequencies corresponding to the semitones of one octave.

A further object is to provide an electrical musical instrument of multioctave range, in which an oscillator is provided for the generation of the tone signals of the twelve semitones of each octave, and in which key operated means are provided to tune the oscillators to the particular semitone frequency selected by the keys.

A further object is to provide an electrical musical instrument having two keyboards playable respectively by the right and left hands of the musician, in which one keyboard is utilized to select the octave of the note to be sounded, while the other keyboard is utilized to select the particular semitone of the selected octave.

A further object is to provide an improved means for suppressing transients introduced upon closure of key operated switches.

A further object is to provide an improved electrical musical instrument in which arpeggio and glissando-like effects may be produced with great facility.

A further object is to provide an improved electrical musical instrument in which the tone may be varied readily from the bright quality of orchestral strings to the mellow qualities of the wood-winds and flutes.

A further object is to provide an improved vibrato mechanism for electrical musical instruments in which the rate and amount of vibrato may readily be controlled.

A further object is to provide an electrical musical instrument which may be tuned readily by means of a single tuning element, and in which the tuning is very stable.

A further object is to provide an improved electrical musical instrument of the melody type in which the volume and expression ranges are greater than those of most conventional musical instruments.

A further object is to proivde an electrical musical instrument having an improved intensity envelope control means whereby percussive as well as sustained tones may be produced.

A further object is to provide an electrical musical instrument requiring limited playing technique on the part of the musician, and which can thus be played with satisfaction by the novice, but which nevertheless provides for a sufficient variety of musical results to attract the expert musician.

A further object is to provide an electrical musical instrument in which the depression of a key results in the sounding of a tone including a fundamental and a plurality of harmonics, and in which the pitch of the fundamental is determined by control means other than said key.

A further object is to provide an improved electrical musical instrument having a plurality of signal generators for providing musical frequencies at octave intervals, and in which closure of one switch selects the generator, or generators, from which the signal is to be derived, while the other switch determines the semitone pitch of the selected generator or generators.

A further object is to provide an improved electrical musical instrument of the melody type in which a plurality of notes in octave relationship may be played simultaneously.

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

Figure 1 is a perspective view of the complete instrument;

Figures 2, 2*a*, 3 and 4 together constitute a wiring diagram of the complete instrument; and

Figure 5 shows a modified form of volume control.

General description

As shown in Figure 1, the instrument may comprise a cabinet **10** in which is contained the loud speaker **12**, as well as the various tubes, switches, and wiring of the instrument, although if desired, the speaker **12** may be mounted in a unit separate from the cabinet **10**.

The cabinet, which in effect constitutes the console of the instrument, has two keyboards.

The left hand keyboard consists of keys I, II, III, IV, V and VI, while the right hand keyboard consists of twelve keys of the pianoforte type which are marked with reference characters C# to C in accordance with the usual system of note designation.

Various manually operable control keys and knobs are located adjacent the key manuals. Their functions are briefly as follows: Knob KL4 adjusts the extent or width of the vibrato; key KS45 controls the line switch; knob KL3 is used for tuning the complete instrument; KS55 controls a low pass filter to provide a mute effect; keys KS1 to KS6 control resonant filters in the output circuit for controlling the tone quality; key KP2 controls the potentiometer for adjusting the over-all volume; key KS36 controls the intensity envelope or attack of the tone; KS39 controls the vibrato; and lever KP1 is adapted to be operated by the knee of the player and controls the volume or expression.

The cabinet 10 is provided with a music rack 14 and has an extension cord 16 connected thereto and provided with a plug for connection to a source of power.

It will be understood that the instrument is played by depressing one or more of the six octave keys I to VI, and simultaneously therewith, or immediately thereafter, depressing one of the semitone selector keys C# to C, whereupon the selected semitone of the selective octave will be sounded, the tone quality, the intensity envelope of the tone, and the volume thereof being controlled by the various controlling keys which have been mentioned.

Power supply system

Any suitable form of power supply system may be utilized which will provide the required voltages for the operation of the various circuits. The power supply system shown by way of illustration in Fig. 2*a* comprises a transformer T1, the primary of which is adapted to be connected to a source of current by a switch S45 controlled by key KS45. The secondary winding of the transformer is connected in the usual manner to the plates of a rectifier tube V12. The output of the tube V12 is connected through a filtering mesh consisting of inductances L1 and L2 and condensers C1, C2 and C3 with a voltage divider resistance R1.

The resistance R1 is tapped at various points to provide the desired voltages on terminals RA, RB, RC, RD and RE. As illustrative, the voltage of the terminal RA may be +250, that of terminal RB +200, and those of terminals RC, RD and RE of increasing negative value suitable for providing grid bias.

The transformer T1 is provided with tertiary windings 18 and 20 for the heaters of tube V12 and the remaining tubes respectively.

The controlling oscillator

The controlling oscillator shown in Fig. 2 may be any suitable design capable of generating audio frequencies throughout the range of the highest octave of the instrument, and is illustrated as comprising a twin triode V1, which may be of the '53 type (illustrated as two triodes V1*a* and V1*b* for the sake of clarity), in which the cathodes are interconnected and biased by resistor R6 having a by-pass condenser C6. The plate voltages for the tube V1 are provided through a resistor R9, one end of which is connected to the terminal RA, and the other end of which is connected to ground through a condenser C7. R9 and C7 serve as a filter to prevent reflection into the power supply system of changes in potential in the plate circuits of the tube V1. The plate of the triode V1*b* is connected to the resistance R9 by a load resistor R7, while the plate of the triode V1*a* is connected to the resistor R9 through load resistors R4 and R5. The grid of the triode V1*b* is connected through a condenser C5 to a terminal between the resistors R4 and R5, and is connected to ground through a high resistance R3. The plate of the triode V1*b* is connected through condenser C4 and resistance R2 with the grid of triode V1*a* to provide the necessary feedback.

There are a number of means provided for tuning the controlling oscillator. The tuning means comprises generally an inductive-reactive mesh connected between the grid and cathode of the triode V1*a*. This tuning means comprises variable inductances L3 and L4, and capacitances C8 to C31 inclusive. The condenser C20 to C31 inclusive are respectively in shunt with the condensers C8 to C19 inclusive, and may therefore be considered in the nature of trimmer condensers for the purpose of simplifying the selection of proper capacitances. Thus, the condensers C8 to C19 may be standard condensers of approximately the correct capacitance, while condensers C20 to C31 may be considered as relatively smaller condensers provided for the purpose of regulating the capacitance between successive condensers C8 to C19 to the exact values required. The condensers C19 and C31 being the last of the series of condensers in shunt, are connected to ground. Either the whole of the variable inductance L4, or a portion thereof, is connected in series with the inductance L3, and since the inductance L4 has one terminal grounded, the inductances L3, L4 and condensers C8 to C31 form a tuned resonant circuit controlling the frequency of the oscillator V1.

To vary the tuning of the instrument as a whole, the control knob KL3 is operated to adjust the reactance of the inductance L3. To vary the frequency of the oscillator in semitone steps, switches S19 to S29 are provided, these switches being operated respectively by the keys C# to B respectively. For the sake of simplicity, there is no switch corresponding to the switches S19 to S29 for key C, and the controlling oscillator will thus oscillate at the frequency of the note C when none of the keys C# to B are depressed.

Each of the switches S19 to S29 is operative effectively to shunt to ground all of the condensers C8 to C31 which are located to the right (Fig. 2), of the switch, so that only those to the left of the switch are effective in providing the tuning capacitances. The resistors R15 to R25 which are respectively in shunt with the condensers C21 to C31 are of high value so as to have a negligible effect upon the tuning of the oscillator. These resistances are provided for varying the grid bias on the controlled oscillator tubes as will be pointed out hereinafter.

The vibrato mechanism

The vibrato mechanism comprises a vibratory spring reed 22 of magnetic material, one end of which is attached to a rigid support 24, and the other end of which carries a weight 26. The position of the weight 26 on the reed 22 may be adjusted since the weight is clamped to the reed by means of a bolt 28 which extends through a longitudinal slot in the reed, thus permitting adjustment of its frequency of vibration. The reed is maintained in vibration by an electromagnet 30, one end of which is connected to the terminal RA through a resistance R11, and to ground through a condenser C33. R11 and C33 serve as a filter to prevent reflection into the power supply system of fluctuating voltages appearing in the winding of the electromagnet 30. The other terminal of the winding of electromagnet 30 is connected to a contact switch S44 which is connected to ground through a high resistance R10.

Assuming that the reed has been manually vibrated, it will, upon its upward swing, close the switch S44, thus energizing the electromagnet 30, causing the latter to attract the reed 22 and pulling the reed downwardly to break the contact S44. The resistance R10 serves merely as a means to prevent undue sparking across the contacts of interrupter switch S44, the switch S44 and electromagnet 30 thus serving to maintain the reed 22 in vibration. A second contact switch S43 is adapted to make contact with the reed during approximately one half the vibratory cycle thereof, the switch S43 being adapted to be connected through conductor 32 with either switch contacts 41 or 42, as determined by the setting of the switch key KS39. This switch key also controls a pair of switches S39 and S40 by which the inductance L3 is connected respectively, either in series with the inductive winding L4 or in series with only approximately one half the inductance of the inductance L4.

In normal operation when the vibrato is not to be utilized, the key KS39 is in such position that switches S39, S41 and S42 are open and S40 is closed. It will be noted that under these circumstances, the vibrato mechanism is ineffective, and only a part of the inductance L4 is connected in series with the inductance L3. When, however, it is desired to use the vibrato device periodically to vary the frequency of the oscillator through a wide range at vibrato periodicity (which may be in the order of 7 c. p. s.), the key KS39 is operated in a manner to close switches S39 and S41, under which conditions it will appear that the inductance L4 is in series with the inductance L3 whenever the vibrato switch S43 is opened, and that the inductance L3 is connected directly to ground (shunting the inductance L4) whenever the vibrato switch S43 is closed. The variation in frequency of the controlling oscillator effected by the periodic opening and closing of the switch S43 under these circumstances may be varied by means of the control knob KL4, which varies the effective reactance of the inductance L4, preferably by changing the amount of iron in the core thereof.

It will be noted that this variation in frequency caused by the periodic closure of the vibrato switch S43 causes a periodic shift in frequency above and below that of the normal frequency at which the controlling oscillator operates, because under such normal conditions only approximately one half of the inductance L4 is in the tuned circuit, whereas when the vibrato device is rendered operative, the whole of the inductance L4 is either connected in series with the inductance L3 or is shunted. By virtue of the fact that the vibrato device operates upon the inductance branch of the tuning mesh, the variation in the negative reactance of the mesh controlled by keys C# to B is not affected, and the condensers C8 to C31 are effective to raise or lower the frequency of the oscillator in semitone steps irrespective of whether all, one half, or none of the inductance L4 is connected in the resonant tuning mesh.

When a narrow vibrato is desired, the key KS39 is shifted to a position such that the switches S41 and S42 are open, and switches S39 and S42 are closed. Under these circumstances the vibrato switch 43 will be effective periodically to shunt the lower portion of the inductance L4. Thus, when the switch S43 is closed, only the upper portion of the inductance L4 will be in series with the inductance L3 to provide the inductive reactance for the tuning mesh, whereas when the switch S43 is open, all of the inductance L4 will be in series with the inductance L3 to provide such inductive reactance. Under these conditions of operation, it will be apparent that the vibrato shift will be between the normal frequency of the controlling oscillator, and a frequency slightly above the normal frequency. Thus, the mean frequency of the oscillator will be shifted slightly, but this shift in frequency will not be sufficiently great to be noticeable to the ordinary listener.

Controlled oscillators

There is provided for each octave of the instrument an oscillator which may oscillate at any one of the twelve semitone frequencies of its particular octave. Since the instrument herein described has a compass of six octaves, there are six such controlled or slave oscillators, each comprising a gaseous discharge tube of the three electrode type. Tubes such as the type 885 are satisfactory for this purpose and are illustrated in Fig. 3 as tubes V2 to V7 inclusive.

A signal from the output plate circuit of the triode V1*b* is impressed upon the grid of tube V2 through a blocking condenser C32 and protective resistor R26. Grid bias on the tube V2 is provided through resistances R32 and R38 and through a varying bias mesh connected to a conductor 34 which, as will hereinafter be pointed out, provides an additional variable grid bias voltage for the tubes V2 to V7. The cathodes of the tubes V2 to V7 are connected to ground through resistors R32 to R39 and R38 to R43 respectively in series. Current limiting resistors R68 to R73 are provided in the plate circuits of each of the tubes V2 to V7, the oscillators being coupled in cascade by transformers T2 to T6 inclusive, the plate circuit of the tube V7 having a choke coil T7 in its plate circuit. The plate voltage for the tubes V2 to V7 is provided through a conductor 36 which is connected to the terminal RA through a resistor R50 and grounded through a condenser C45. C45 and R50 serve as a means to prevent reflection into the power supply system of voltage variations resultant from the variations in the load provided by the tubes V2 to V7. Condenser C33 to C38 are connected between the cathodes of the tubes V2 to V7 and their respective B supply line.

The values of resistors R32 and R38 are such with respect to the capacity of condenser C33 that the tube V2 normally oscillates at a frequency close to that of the frequency of the controlling oscillator V1, its frequency of oscillation being stabilized to be exactly that of the oscillator V1 by the controlling signal impressed on the grid of the tube V2 through C32 and R26. In a similar manner, the tube V3 will oscillate at a frequency one half that of the tube V2, and similarly, the oscillators comprising the tubes V4, V5, V6 and V7 will successively halve the frequency of the preceding oscillator. For example, assuming the controlling oscillator to be oscillating at a frequency of 4000 c. p. s., the tube V2 will oscillate at 4000 cycles, V3 at 2000 cycles, V4 at 1000 cycles, V5 at 500 cycles, V6 at 250 cycles and V7 at 125 cycles. Thus, all the controlled oscillators will operate at frequencies which are exact sub-multiples of the frequency of the controlling oscillator (by a factor which is the reciprocal of a power of 2), and thus be in octave relationship. Each positive voltage peak of the signal supplied by the controlling oscillator, and each alternate positive voltage peak of the signals of the plate circuits of the controlled oscillators serve as a means to trip the next succeeding oscillator.

It was previously stated that the values of the elements of each of the relaxation oscillations were so chosen that it would oscillate at substantially the required frequency and that the controlling signal on its grid would be effective to regulate its frequency of oscillation. Since the frequency of the controlling oscillator V1 necessarily shifts through the range of an octave (as the keys C# to C are depressed), it is necessary that the relaxation oscillators V2 to V7 likewise be capable of oscillating at frequencies throughout the range of an octave. In order to insure that the frequency controlling signals impressed upon the grids of the relaxation oscillator should not lose their exact octave controlling function, means are provided to vary the grid bias on the tubes V2 to V7 with the variation in frequency of oscillation of the controlling oscillator V1. This purpose is accomplished by virtue of the fact that all of the grids return circuits of the tubes V2 to V7 are connected to a common conductor **34** which, as appears in Fig. 1, is connected to terminal RA through series resistors R13 and R13*a*, and is connected to ground through resistors R14 and R14*a*, as well as through a series of resistances including resistor R12 and one or more of the resistances R15 to R25 previously described.

The resistances of R14 and R14*a* are small relative to R13 and R13*a* so that there is a substantial voltage drop across R13 and R13*a*. The voltage drop across R13 is determined by the number of resistances R15 to R25 which are connected in series with R12, and this voltage drop determines the voltage drop across R13*a*, and hence the potential of conductor **34**. Of course the potential of the conductor **34** will always be positive with respect to ground, but it will be more or less negative with respect to the cathodes of tubes V2 to V7 because of the fact that these cathodes are connected to ground through relatively high biasing resistances R32 to R37, which are in series with R38 to R43 respectively. The variation in positive potential applied to the grid circuits results in a reduction in negative bias to the oscillator grids as otherwise determined chiefly by resistances R32 to R37.

Since resistances R15 to R25 are successively shunted out of the circuit upon closure of switches S19 to S29 inclusive respectively, the bias voltage appearing across the resistance R14 is lowered as the frequency of the controlling oscillator V1 is lowered. R13*a* is of sufficiently high value that voltage fluctuations in the conductor **34** at the sub-octave frequencies will not be impressed with any substantial strength upon the grid of the triode V1*a*. It will be apparent from the above description that whenever any of the keys C# to C are depressed and the frequency of the controlling oscillator V1 thereby changed, the grid bias, and all of the controlled oscillators V2 to V7 will simultaneously be changed to condition the controlled oscillators for safe operation at the changed frequency. By safe operation is meant that the controlling signals on the grids of each of the controlled oscillators will be effective to control the frequency of oscillation of the tube without possible danger of the controlled oscillator operating at a frequency other than the octave lower than that impressed upon its grid.

Signal switching and volume control

Signals to be keyed to the amplifier are derived from the voltage drop occurring across resistors R38 to R43. These resistors are of low value compared with their associated resistors R32 to R37 inclusive respectively, which latter are one of the principal factors in determining the frequency of oscillation of the oscillators V2 to V7 and may, therefore, be referred to as the "timing resistors." For this reason, the signal voltage for each octave may be adjusted conveniently by varying the values of resistors R38 to R43 without materially affecting the oscillators with which they are associated.

Non-robbing resistors R44 to R49, which are of high value with respect to the resistors R38 to R43 inclusive respectively, are connected in series with transient suppressing condensers C39 to C44 inclusive respectively, and ocative controlling switches S30 to S35 inclusive respectively. Resistors R44 to R49 prevent short-circuiting of one octave generator by the other, when several of them are used simultaneously.

The condensers C39 to C44 function in two ways to prevent keying transients. The waves developed across the resistors R44 to R47 are pulsating direct currents and as such have relatively large direct current components. If these condensers are made critically small, the low order transient components are attenuated more than the high frequencies, and as a result the only part of the transient to pass unattenuated is the high frequency spectrum which lies in the range of the note signal frequency and is therefore effectively masked by the latter, and thus is not noticeable.

It will also be noted that after any of the switches S30 to S35 have been closed for the first time (thus charging their associated condensers C39 to C44), most of the direct current transients will be absent upon subsequent closure of the switches, providing that the time interval between successive operations of the switches is not long enough for the charge to leak from the condensers. As a practical matter, during normal playing of the instrument, there is not sufficient time between successive closures of the switches for the charges on the condensers C39 to C44 to be reduced appreciably by leakage.

The switches S30 to S35 are operated respectively by the octave selecting keys VI, V, IV, III, II and I. A conductor **38** is connected to one pole of each of the switches S30 to S35, and transmits the signal derived from the controlled oscillators upon the selective operations of the keys I to VI to an output transformer T8 (Fig. 4). A low pass filter comprising a mesh consisting of inductances L10, L11 and L12, condensers C55 and C66, and resistances R68 and R69, is adapted to be rendered effectively in circuit with the primary of the transformer T8 upon opening a switch S55 and closing a switch S56. The switches S55 and S56 are controlled by the key KS55.

Inductances L11 and L12 may each have a value of approximately one half that of the inductance L10, and the remaining elements of the filter mesh have such values as to attenuate frequencies above approximately 5000 cycles. It will be understood that the controlled oscillators V2 to V7 provide a signal wave which is of generally saw-toothed shape, and which thus contains high harmonics of appreciable amplitude. By eliminating some of these higher harmonics by means of the low pass filter, the tones may be made more mellow, and thus serve better for providing certain musical effects, such, for example, as the simulation of the piano tone, in which instrument the harmonic development decreases with increases in the pitch of the fundamental.

The secondary of the output transformer T8 has its end terminals connected to the grids of tubes V8 and V9 respectively, which form a push-pull amplifier. The cathodes of the tubes V8 and V9 are connected to ground and the plate current is supplied from terminal RA through resistors R52 and R53, the output of the tubes V8 and V9 being coupled to the next stage of amplification by a transformer T9.

The push-pull arrangement of the keying system serves substantially to eliminate the direct current component in the plate currents of the tubes V8 and V9, which otherwise would give rise to an undesirable transient when the keying switches are closed.

The operation of the keys controls the grid bias on the tubes V8 and V9 and thus, by changing the grid bias at different rates, the intensity envelope of the tones may readily be controlled. The grids of the tubes V8 and V9 are normally biased beyond cutoff. Such bias is applied to these grids through a conductor 40 which is connected to a center tap on the secondary of transformer T8, and is connected to the negative terminal RE of the power supply through resistors R54 and R55, the resistance R55 being adapted to be shunted upon closure of a switch S37. When the grids of the tubes V8 and V9 are thus maintained at the potential of the terminal RE, they are sufficiently beyond cutoff so that no signal can appear across the primary of transformer T9 even though one or more of the switches S30 to S35 is closed. The bias on the grids of tubes V8 and V9 is adapted to be changed to a value to render these tubes capable of conducting the signal to the transformer T9 by the closure of switches S7 to S18, which are connected in parallel, and are operable by the keys C# to C inclusive respectively, as indicated in Fig. 4. The switches S7 to S18 are in series with a group of switches S46 to S51 in parallel, the latter being operated by the keys I to VI inclusive respectively. Thus, upon closure of any one of the switches I to VI, and the closure of any one of the switches S7 to S18, the conductor 40 is connected to ground through resistors R66 and R67, and a condenser C52. A switch S38 is adapted when closed to shunt the resistor R66 and condenser C52.

The switches S7 to S17 are so adjusted as to close after their associated switches S19 to S29 have closed. Switches S46 to S51 are arranged to close after the switches S30 to S35 respectively have been closed. Thus, the sequence of operations is first to tune the instrument to the desired note frequency, and select the desired octave, and then to key the grid bias on the tubes V8 and V9 to permit the selected signal to be transmitted to the transformer T9.

The conductor 40 is connected to ground through condenser C47 which may, upon closure of a switch S36, be shunted by a resistor R51 and condenser C46 in parallel.

For a sustained note having organ-like attack and decay, switches S36 and S37 are closed. Then, when one of the octave switches S46 to S51 and one of the switches S7 to S18 is closed, the potential on condensers C47 and C46 will change from beyond cutoff to a potential providing an operating bias for tubes V8 and V9. The rate at which this change in bias occurs, depends principally upon the capacitance of C46 and C47 and the resistance of R67. Upon release of either one of the keys controlling the switches S46 to S51, or S7 to S18, the tone will commence to decay at a rate determined by the value of resistance R54 with respect to the capacitance of C46 and C47. By making these circuit elements of appropriate values, organ-like attack and decay rates may readily be obtained.

For the production of percussion or piano-like tones, switches S36, S37 and S38 are opened by the operation of the key KS36. Under these conditions, condenser C52 will be at ground potential before the completion of a circuit between it and the conductor 40 by the closure of one of the switches S46 to S51 and one of the switches S7 to S18, but upon depression of the keys to close one switch in each of said groups of switches, the potential of C46 and C57 are immediately put at ground potential, and tubes V8 and V9 rendered fully operative. However, shortly after this circuit has been completed, a voltage division occurs between the combined resistance of R54 and R55, and the combined resistance of R66 and R67 which causes the biasing potential on the grids of tubes V8 and V9 to change gradually toward cutoff potential, with resultant decrease in the amplitude of the signal in the primary of transformer T9.

By proper selection of the constants in the latter circuit, a tone having banjo-like attack and decay characteristics may be obtained. When this effect is desired, the musician should play in a non-legato manner so that the percussion effect may occur with each note as it is played. Many types of tone envelopes are obtainable by proper selection of the values of the condensers C46, C47 and C52, and of resistors R51, R54, R55, R66 and R67. While in a given instrument it may be preferable to use fixed resistors and fixed condensers for these elements, the fact that variations in their values will result in varying the attack and decay characteristics of the tone is illustrated by showing the resistors R51, R54, R66 and R67 and the condensers C46, C47, and C52 as being of the variable type. In actual practice, the variation in the values of these elements will usually be accomplished by switching corresponding elements in shunt.

Volume control

A preamplifier tube V10 has its grid connected to the secondary of transformer T9 through a resistance R56, and the amplitude of the signal is controlled by variable resistance P1 connected between the grid of the tube V10 and the terminal RC of the power supply system, the other terminal of the secondary winding of the transformer T9 being likewise connected to the terminal RC. The resistance R56 is of sufficient value to prevent appreciable changes in the alternating current load of the tubes V8 and V9 upon changes in the volume control resistance P1. If this resistance R56 were not provided, changes in the setting of P1 would be reflected into the plate circuits of tubes V8 and V9 as a change in load which of course would be undesirable since the tubes V8 and V9 should have a constant plate load impedance to alternating currents to insure operation as a class A amplifier. The variable resistance may be of the type shown in the application of Laurens Hammond, Serial No. 91,284, filed July 18, 1936, and be mechanically connected for operation by the lever KP1 which is positioned for convenient actuation by the knee of the player.

The plate of the tube V10 is connected through the primary of a transformer T10 to the terminal RA for the B voltage supply. The secondary winding of transformer T10 is connected in series with a resistance R80 forming a potentiometer P2, the adjustable contact of which is connected through a resistance R58 to the control grid of a pentode power amplifying tube V11. The potentiometer P2 is adapted to be operated by the key KP2 and may serve as a pre-set volume control to adjust the tone volume to the size and acoustic properties of the room in which the instrument is played, and to the character of the selection being rendered.

The adjacent terminals of the secondary winding of the transformer T10 and resistance R80 are connected to the biasing potential terminal RD of the power supply system. Also connected between the grid of tube V10 and the terminal RD are a series of filtering and resonant meshes by means of which the quality of the tone signal impressed upon the grid of the tube V11 may be varied.

The first of these meshes consists of a resistance R59 which, by the operation of a three-way switch S1, may be shunted by a conductor 46 or a resistor R60, and constitutes an adjustable volume control.

The second mesh which may be connected in series with the first, comprises an inductance L5 which may be shunted either by a resistance R61 or a conductor 48, depending upon the position of a switch S2. This mesh attenuates low frequencies, relative to the higher frequencies, and results in a bright tone.

The third mesh consists of an inductance L6 which is in parallel with a condenser C48, L6 and C48 being adapted to be shunted either by a resistance R62 or a conductor 50, depending upon the position of a switch S3. This mesh may be resonant at a relatively high pitch.

The fourth and fifth meshes may be similar to the third mesh, and are shown as comprising inductances L7 and L8, condensers C49 and C50, resistances R63 and R64, conductors 52 and 54 and three-way switches S4 and S5. These meshes may be resonant at intermediate and low pitches respectively. The inductances L6, L7 and L8 and condensers C48, C49 and C50 will of course be of different values so as to form filters effective to pass the aforesaid different bands of frequencies.

The last mesh of the series comprises a condenser C51 which may be shunted by a resistor R65 or a conductor 56, depending upon the position of switch S6. This mesh emphasizes the lower pitch frequencies in the output of the speaker.

It will be understood that the switches S1 to S6 are operable by the keys KS1 to KS6 inclusive respectively.

The output circuit of the tube V11 includes the speaker 12 and is connected to the terminal RA of the power supply system. The resistor R58 prevents appreciable reflection of changes in impedance of the tone control circuits from being reflected back into the output circuit of tube V10.

As illustrative, the tubes V8, V9 and V10 may be triodes of the '56 type, while the tube V11 may be a power pentode of the '2A5 type.

In Figure 5, I have shown a modified form of volume control for the instrument, in which the output circuit of the last stage of the amplifier, tube V11, includes the primary of a transformer T11, the secondary of which is in series with the voice coil 58 of a dynamic speaker 60. The field coil 62 of the speaker 60 is energized by being connected to the terminal RA through a potentiometer P3, the movable contact of which is adapted to be operated through a flexible Bowden control wire, by means of a pedal 64 pivoted to a heavy block 66, which may rest upon the floor. The potentiometer P3 could of course be operated by other suitable means, such as a knee operated lever.

Because of the relatively great inductance of the field winding 62, changes in the resistance of variable resistance P3 will not cause rapid changes in the sound output of the speaker. Thus, noise due to the transients incidental to rapid changes in the exciting voltage for the field coil, will be avoided. By utilizing this method, a swell control for an electrical musical instrument may be made in which the variable resistance consisting of a small number of fired resistors may be effective smoothly to control the volume over a wide intensity range.

Operation

Having closed the line switch S45 and started the vibration of the vibrato reed 22, and having set the desired combination of controls, the instrument will be in condition for the rendition of any melodic selection which lies within the compass of the instrument. It will be understood that the instrument will be used ordinarily to play but one note at a time, although it is possible to play chords consisting of unison or octave notes.

In playing the melody, the musician selects the octave range of the note to be played by depressing the desired one of the keys I to VI and immediately thereafter, or simultaneously therewith, depressing the selected key C# to C. Upon depressing one of the keys I to VI, a signal from one of the relaxation oscillators, which are of course not necessarily gas tube oscillators but may be of any other suitable type, is transmitted through the conductor 38 to the grids of the amplifier tubes V8 and V9. These tubes are, however, normally biased beyond cutoff and thus do not transmit the signal to their output circuits. Depression of one of the octave keys I to VI also closes one of the switches S46 to S51, but such switches are ineffective to change the bias upon the grids V8, V9 unless one of the note selecting keys C# to C is also depressed to close its associated switch S7 to S18.

Until one of the keying switches C# to C is closed, the controlling oscillator will be tuned to the frequency of the note C of the highest octave, and the controlled oscillators will of course each be oscillating at the frequency of the note C of their respective octaves. However, upon depression of one of the note selecting keys C# to C, one of the switches S19 to S29 will be closed. (The key C does not operate a switch corresponding to switches S19 to S29, since these switches are for the purpose of tuning the oscillator to the particular semitone frequency desired, and the circuit is so arranged that the oscillator normally oscillates at the frequency of the note C.) In addition to closing one of the switches S19 to S29, the operation of a note selecting key will close one of the switches S7 to S18, and thus complete a circuit from ground to the grids of the tubes V8, V9. It has been previously explained how the rate at which the bias potential upon the grids of the tubes V8 and V9 may be controlled in a wide variety of ways, to produce different intensity envelopes corresponding to sustained notes of the organ type, percussive notes of the piano and banjo type. The player changes the volume for expression purposes by operation of the lever KP1 which results in changing the effective gain of the amplifier tube V10. The quality of the tone is controlled by the switches S1 to S6 which are operated in any desired combinations to attenuate certain bands of frequencies and thus effectively vary the quality of the tones produced.

Upon closure of any of the note selecting key switches S19 to S29, the frequency of oscillation of the controlling oscillator is immediately shifted due to the change in a negative reactance of its tuning circuit. At the same time, the grid bias on all of the controlled oscillators is changed slightly so as to assure that all of these oscillators will continue to oscillate at an octave frequency which is a sub-multiple of the controlling oscillator frequency, with the exception of the relaxation oscillator V2 which of course is maintained in oscillation at the same frequency as the controlling oscillator.

As previously intimated, it is not essential that gas tube relaxation oscillators be utilized, but any other suitable oscillators such as multivibrators or oscillators employing vacuum tubes, such as shown in the patent to Gilbert Smiley Reissue No. 20,831, may be employed.

While one of the stated objects of the invention was to provide a simple instrument which could be manufactured at a low cost (and for this reason the keyboard is limited to twelve keys in addition to the octave selecting keys), it will be apparent that the keyboard range could readily be extended to any desired length. In this event, some or all of the octave keys could be eliminated since the switches operated thereby could be operated by the note selecting keys for the corresponding octaves.

The instrument as shown, however, presents a number of advantages because of its simplicity and because runs and arpeggios may be played with great facility. This is due to the fact that the note selecting keys may be played with one hand without the necessity of shifting the position of the hand or employing complicated fingering technique. For example, an arpeggio consisting of the notes C, E, G repeated in successive octaves may be rendered with great facility by the player, since the position of his right hand is not changed and he merely repeats the operation of pressing the keys C, E, G, and for each repetition presses a different one of the octave selecting keys I to VI. The musical effect may be enhanced if, during the execution of such arpeggio, two or more of the octave selecting keys are simultaneously pressed. Under these circumstances the notes in the different octaves corresponding to the keys depressed will be sounded simultaneously.

While I have disclosed herein particular embodiments of my invention, it will be apparent to those skilled in the art that numerous variations and alterations may be made without departing from the underlying principles thereof. I therefore desire by the following claims to include within the scope of my invention, all such modifications and variations of the invention shown herein, by which substantially the results of the invention are obtained in substantially the same way, by the same or equivalent means.

I claim:

1. For use in an electrical musical instrument of multi-octave range having a plurality of keys, and an output circuit including electroacoustic translating means; the combination of a variable frequency generator of electrical impulses for each octave of the range of the instrument, circuits controlled by said keys simultaneously to vary the frequencies of said generators throughout their respective octave ranges, so that corresponding notes in their respective octaves will be generated thereby, and means connected between said generators and said output circuit for controlling the transmission of impulses from selected generators to said output circuit.

2. The combination set forth in claim 1 in which each of said generators includes an electron discharge device, and in which means are provided to interconnect said devices in cascade so as to operate at frequencies such that each device controls the frequency of operation of the device for the next lower octave.

3. The combination set forth in claim 1, in which a master frequency controller is provided having means for controlling the frequency of the generator for the highest octave, and in which means are provided to interconnect said generators for the remaining octaves in cascade and to said highest octave generator.

4. The combination set forth in claim 1 in which each of said generators includes an electron discharge device having a control grid, and in which the key controlled means for varying the frequencies of said generators includes a circuit for changing the bias on the grids of said devices.

5. The combination set forth in claim 1 in which there is provided an oscillator for stabilizing the frequencies of said generators, and in which the key controll means for varying the frequencies of said generators includes reactances rendered effective by operation of said keys for tuning said oscillator to the various notes of an octave.

6. In an electrical musical instrument, the combination of a controlling oscillator, a plurality of controlled oscillators having their frequencies stabilized by said controlling oscillator, said controlling and controlled oscillators being adjustable to supply frequencies throughout ranges of octave extent, selectively actuated keys, means operated thereby for tuning all of said oscillators to cause them to oscillate at the frequencies of corresponding semitone notes in different octaves of the musical scale, a normally ineffective signal transmission circuit for conveying the signal to means for utilizing it, and

means operated by said keys to render said transmission circuit operative.

7. For use in an electrical musical instrument having keys and an output circuit including electroacoustic translating means; the combination of a plurality of frequency locked generators for generating electrical impulses of frequencies bearing octave relationship to one another, each of said generators being capable of supplying frequencies throughout the range of its octave, selective key switch controlled means for causing said generators to generate frequencies of any selected octave interval notes of their respective octaves, and selectively operated switch means for controlling the transmission of signals from said generators to said output circuit.

8. For use in an electrical musical instrument, the combination of a plurality of electrical signal generators, each capable of generating frequencies throughout the range of at least one octave, means for coupling said generators for operation at frequencies bearing octave relationship to one another, means connected to said generators for simultaneously changing the frequencies of operation of all of said generators to the frequencies of selected corresponding semitone notes in their respective octave ranges, an output circuit, and selectively operated key switch means for connecting a selected generator to said output circuit.

9. In an electrical musical instrument having a master oscillator and a plurality of controlled oscillators each including an electrical discharge device having a control grid, a tuning circuit for said master oscillator including a plurality of condensers connected in series, a plurality of keys, switches operated by said keys for selectively shunting one or more of said condensers from said tuning circuit, a common circuit for controlling the biasing potentials on the grids of said controlled oscillators, and means controlled by said keys for changing the potential on said last-named circuit.

10. The combination set forth in claim 9 in which the means controlled by said keys for changing the biasing potential on the grids of the controlled oscillators comprises voltage divider resistances including a series of resistance elements connected in parallel respectively with said condensers.

11. In an electrical musical instrument, the combination of a master oscillator, a plurality of generators of musical frequencies bearing octave relationship to the frequency of said master oscillator and having their frequencies stabilized by said master oscillator, keys, means controlled by said keys for tuning said master oscillator to the frequency of any selected note of an octave, and means controlled by said keys for conditioning said generators to cause them readily to change their frequencies of operation simultaneously with changes in the frequency of said master oscillator.

12. For use in an electrical musical instrument having a plurality of tone signal sources, an output circuit including a push-pull amplifier and electroacoustic translating means, and a plurality of keys; the combination of a source of bias controlling potential for said push-pull amplifier, a condenser and resistance network, and switches controlled by said keys for connecting said bias controlling potential source to said push-pull amplifier through said network.

13. An electrical musical instrument comprising a plurality of electron discharge device generators of electrical signals of frequencies bearing octave relationships to one another, each of said generators being tunable throughout the range of an octave, key controlled means for simultaneously and substantially instantaneously tuning said generators to the frequencies of selected corresponding notes in their respective octaves, and means for selectively utilizing the signals supplied by said generators.

14. In an electrical musical instrument in which a master oscillator is provided to control the frequencies of operation of a plurality of controlled generators of electrical signals, and in which the master oscillator is provided with a tuning circuit including a plurality of inductances, the combination of a circuit interrupter operating continuously at a vibrato periodicity, and selectively closed switch controlled circuits, each including said interrupter, for shunting one or both of said inductances from said tuning circuit during the intervals that the interrupter is in closed circuit condition.

15. In an over-all expression control apparatus for use in an electrical musical instrument having a generating system and an output system for receiving signals from said generating system, the combination of a reactive element in said output system, the direct current potential on the terminals of said element determining the intensity of the sound produced by the instrument, a source of direct current, and means to vary the voltage supplied from said source to said reactive element, whereby changes in the direct current flow through said reactive element will be gradual due to the reactance of said element.

16. For use in an electrical musical instrument having a generating system and an output system for receiving signals from said generating system, an over-all expression control apparatus comprising a reactive element in said output system, the direct current flow to which determines the over-all sound output of the instrument, a source of direct current potential, and a variable means for regulating the flow of direct current to said reactive element.

17. In an electrical musical instrument, apparatus for over-all expression control comprising a dynamic speaker having a field coil, and manually operable means for controlling the current flow through said coil whereby the rate of change of current flow through said coil will be limited by the inductance thereof, and changes in volume will be correspondingly gradual, said last named means being constructed and arranged to increase current flow through said field coil for increased volume of output of said speaker.

18. In an electrical musical instrument, in combination, a first circuit, a master oscillator included in said first circuit, a plurality of reactances connected for selective operation in said circuit for the purpose of rapidly tuning said master oscillator to different frequencies covering a range as large as one octave, a second circuit, a slave generator connected in said second circuit for producing frequencies one octave lower than the frequencies of said master oscillator, a connection for impressing various direct current voltages on said slave generator to condition said generator to operate at a frequency approximately one octave below that of said master oscillator, and a connection for impressing an alternating current signal from said master oscillator on said slave generator accurately to control the frequency of said generator to the exact octave relationship.

19. In an electrical musical instrument, in combination, a master oscillator, a plurality of reactances arranged for connection to said master oscillator to tune the latter to the frequency of a note of the musical scale, a controlled generator for supplying a frequency one octave lower than that of said master oscillator, a plurality of keys, circuits completed by switches operated by said keys respectively to render a predetermined number of said reactances effective to tune said master oscillator, circuits completed by switches operated by said keys to condition said controlled generator for operation at a frequency an octave lower than that of said master oscillator, and means deriving a stabilizing signal from said master oscillator and impressing it upon said controlled oscillator, thereby to cause the latter to operate at a frequency exactly an octave lower than that of said master oscillator.

20. In an electrical musical instrument, in combination, a master oscillator, a plurality of reactances arranged for connection to said master oscillator to tune the latter to the frequency of a note of the musical scale, a controlled generator for supplying a frequency one octave lower than that of said master oscillator, a plurality of key operated switches, circuits completed by said switches respectively to render a predetermined number of said reactances effective to tune said master oscillator, means to condition said controlled generator for operation at a frequency approximately an octave lower than that of said master oscillator, and means deriving a stabilizing signal from said master oscillator and impressing it upon said controlled generator, thereby to cause the latter to operate at a frequency exactly an octave lower than that to which said master oscillator is tuned.

21. For use in an electrical musical instrument including an amplifying and electroacoustic translating system, a plurality of sources of electrical impulses of musical frequency and of different octave ranges, each variable throughout its range, key controlled means for tuning all of said sources simultaneously to the frequencies of corresponding notes in their respective ranges, and key controlled means for selecting one of said sources and causing transmission of the impulses therefrom to the amplifying and electroacoustic translating system.

22. For use in an electrical musical instrument including an amplifying and electroacoustic translating system, a plurality of electron discharge devices and associated circuits constituting generators of electrical impulses of musical frequency and of different octave ranges, each variable throughout its range, key controlled means for tuning all of said generators simultaneously to the frequencies of corresponding notes in their respective ranges, and key controlled means for selecting one of said generators and causing transmission of impulses therefrom to the amplifying and electroacoustic translating system.

23. For use in an electrical musical instrument, the combination of a plurality of generators of controllable musical frequencies in octave relationship, key operated switch means for regulating the frequencies of said generators each throughout the range of an octave, a key operated switch connected to one of said generators for selecting that particular generator, and an output circuit receiving the electrical impulses from the generator selected by said switch.

24. For use in an electrical musical instrument of the melody type having many keys and having an output circuit, the combination of a master generator, a plurality of slave generators having their frequencies stabilized by said master generator, means for tuning said master generator to any one of a plurality of musical note frequencies, and key operated means for playing successively every note of a musical scale throughout a range of a plurality of octaves from said generators, said key operated means including key controlled switch completed circuits selectively connecting said generators to the output circuit of the instrument and connecting said tuning means to said master generator, said circuits being sequentially arranged in such order that in playing a musical scale from a high pitch note to a low pitch note the frequency of said master generator decreases by steps of one note for a range of one octave less one note and repeats said procedure for the production of succeeding notes.

25. For use in an electrical musical instrument of the melody type having many keys and an output circuit, in combination, one master generator, tuning means connected to said master generator for controlling the frequency thereof, a second generator, locking means connected between said master generator and said second generator for locking the frequency of said second generator to that of said master generator in exact octave relationship, key controlled circuits for selectively connecting said master generator and said second generator to said output circuit, and circuits controlled by said keys to render said tuning means effective.

26. In an electrical musical instrument, the combination of an oscillator having a resonant tuning circuit determining the frequency of oscillation thereof, said tuning circuit including a plurality of capacitances, playing key operated means for selectively connecting said capacitances in said tuning circuit, a relatively fixed inductance, a second inductance, a switch for effectively connecting said second inductance in said tuning circuit, and means for operating said switch at a vibrato periodicity.

27. In an electrical musical instrument having a plurality of generators of electrical impulses, each generator being adapted to supply musical frequencies throughout the range of substantially an octave, key operated means for selecting the outputs of said generators, and a transient filter mesh in the output circuit of each of said generators to greatly attenuate frequencies lower than the lowest frequency which the generator is adapted to supply.

28. In an electrical musical instrument having a plurality of octave selecting keys, a plurality of keys for determining the note of the octave to be played, an amplifier, and switches operated respectively by said keys, and circuits including said switches and effective to render said amplifier operative only when at least one key of each group of keys is operated.

29. For use in an electrical musical instrument having an output circuit including an amplifier with a terminal the potential of which determines the degree of amplification of the amplifier, the combination of a point of fixed direct current potential, a key operated switch, and a mesh including said switch and connecting said point of fixed direct current potential to said terminal, said mesh comprising: a resistor, a capacity, and said switch connected in series be-

tween said point of fixed potential and said terminal; a second resistor shunting said capacity, a second capacity and a third resistor shunting said second capacity, said second capacity and third resistor being connected between said terminal and said point of fixed potential.

30. For use in an electrical musical instrument having an output circuit including an amplifier with a terminal the potential of which determines the degree of amplification of the amplifier, the combination of a point of fixed direct current potential, a key operated switch, a mesh including said switch and connecting said point of fixed direct current potential to said terminal, said mesh comprising: a resistor, a capacity, and said switch connected in series between said point of fixed potential and said terminal; a second resistor shunting said capacity, and a second capacity connected between said terminal and said point of fixed potential.

31. In an electrical musical instrument comprising an oscillator having means for tuning it to any one of a plurality of musical note frequencies, an amplifier, a plurality of keys, a plurality of switches operated successively by each of said keys, and connections between said switches and said tuning means and amplifier, respectively, arranged to be effective upon depression of one of said keys, first, to cause said tuning means to tune said oscillator to the note frequency represented by the depressed key and to make a connection between said oscillator and said amplifier, and thereafter to render said amplifier effective.

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