Aug. 25, 1942. J. M. HANERT 2,294,178

ELECTRICAL MUSICAL INSTRUMENT

Filed Nov. 10, 1939 3 Sheets-Sheet 1

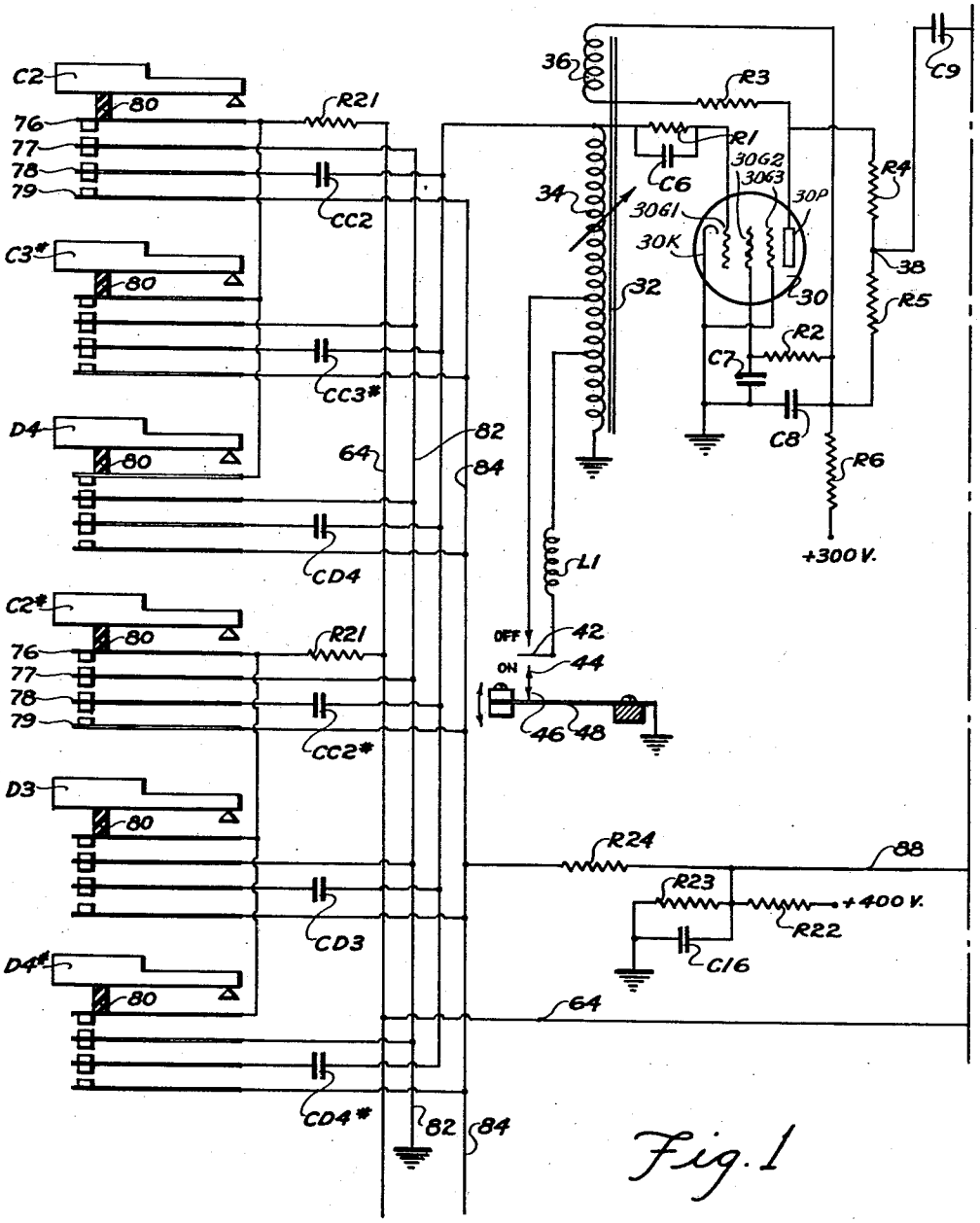

Fig. 1

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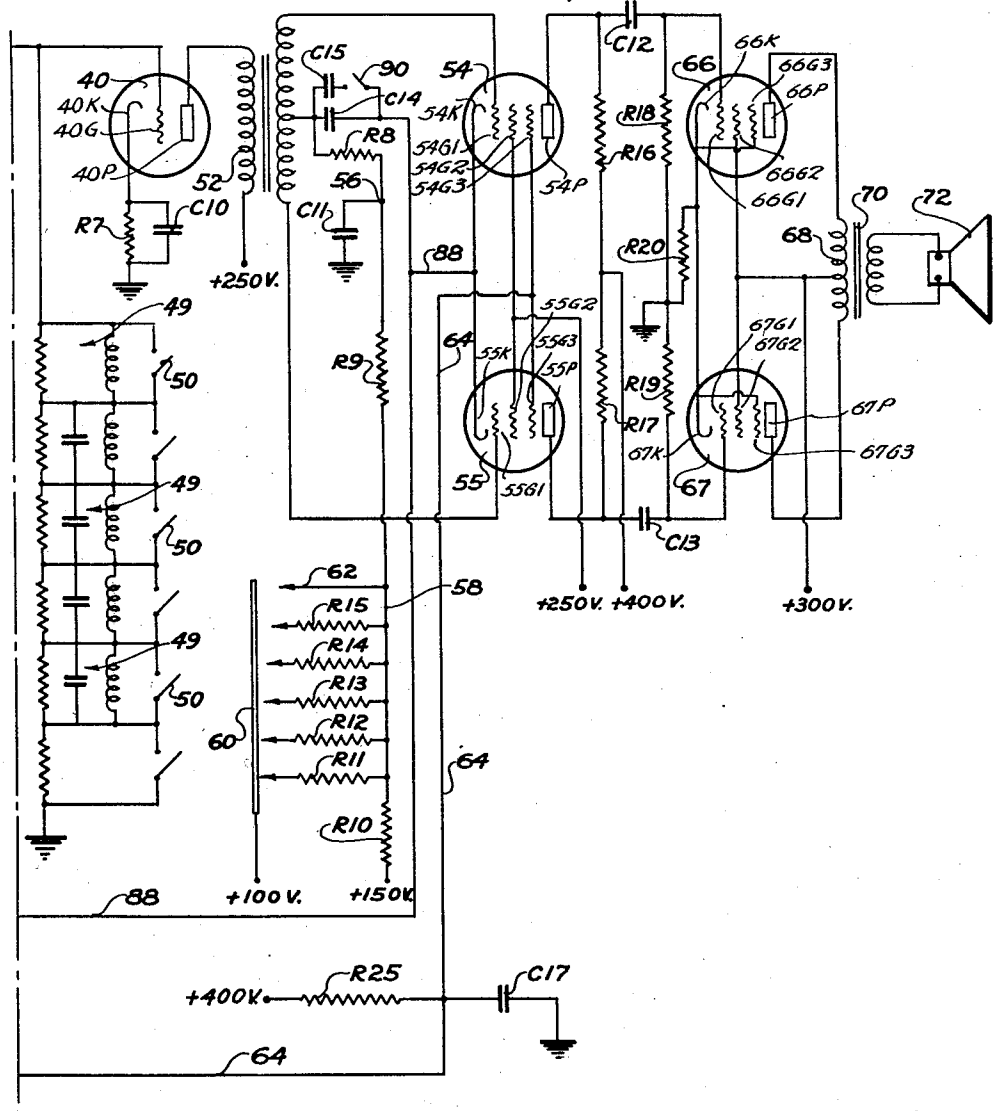

Fig 2

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Filed Nov. 10, 1939 3 Sheets-Sheet 3

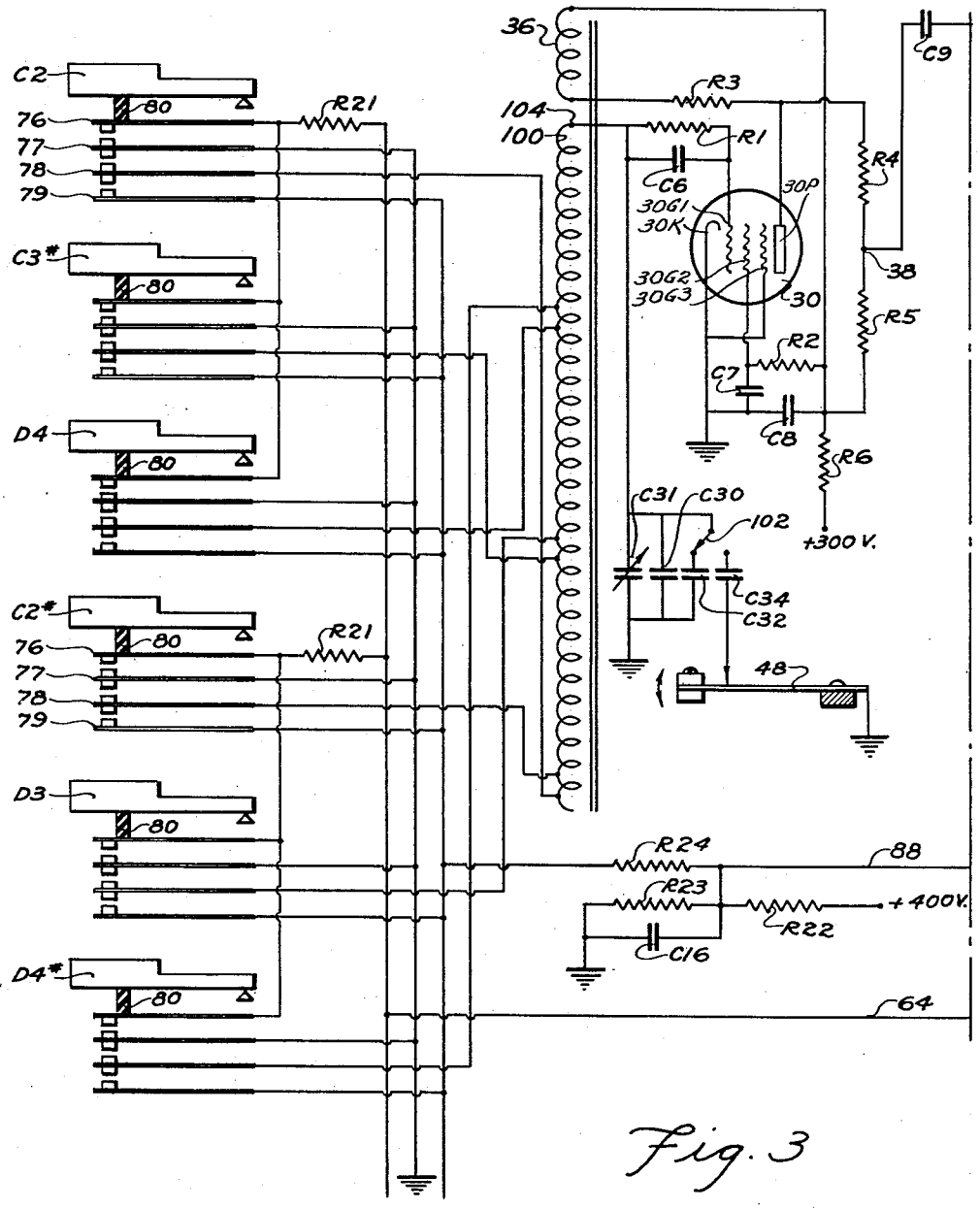

Fig. 3

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Patented Aug. 25, 1942 2,294,178

UNITED STATES PATENT OFFICE

2,294,178

ELECTRICAL MUSICAL INSTRUMENT

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

Application November 10, 1939, Serial No. 303,728

14 Claims. (Cl. 84—1.20)

My invention relates generally to electrical musical instruments, and more particularly to improvements in instruments of the melody type wherein changes in pitch of the tone produced are obtained by changing the frequency of oscillation of an electron discharge device oscillator.

It is the primary object of my invention to provide a very simple form of electrical musical instrument which may be manufactured at relatively low cost, but which will nevertheless be capable of providing a large variety of interesting and entertaining musical effects.

A further object is to provide an improved electrical instrument of the melody type having a single oscillatory generator for providing the tone frequencies, with simplified key controlled means for tuning said generator.

A further object is to provide an improved keying circuit for an electrical musical instrument in which the note frequencies are generated by an adjustable frequency oscillator, the keying circuit including means for paralyzing the amplifier of the instrument when two or more keys are simultaneously depressed.

A further object is to provide an improved electrical musical instrument of the melody type, in which the potential upon the suppressor grids of a pair of tubes in a push-pull amplifier stage are brought to a potential beyond cutoff whenever two or more keys are simultaneously depressed.

A further object is to provide an improved melody type electrical musical instrument having means to suppress undesirable transients irrespective of whether the instrument is played with a legato or non-legato touch.

A further object is to provide an improved electrical musical instrument of the melody type having means for providing a smooth and controlled rate of tonal attack and decay.

A further object is to provide an improved oscillatory generator for an electrical musical instrument of the melody type.

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

Figures 1 and 2 together constitute a wiring diagram of one form of the invention; and

Figures 2 and 3 taken together constitute a wiring diagram of a modified form of the invention.

General description

In general, the instrument of my invention will comprise a keyboard consisting of one or more octaves of keys, similar in general to the keys of a piano keyboard, or of any other suitable construction, the instrument herein described being assumed to comprise three octaves of keys designated herein as keys C2 to B4, in accordance with a common system of musical note designation as set forth in Hammond Patent No. 1,956,350, granted April 24, 1934. Keys C2, C3#, D4, C2#, D3 and D4# are shown in the drawings as representative of the three octaves of keys. Each of the keys successively operates three switches, the first of which controls the potential impressed on the suppressor grids of a pair of tubes of a push-pull stage of the amplifier of the instrument; the second of which operates to tune the oscillator to the frequency corresponding to the key depressed; and the third of which renders the amplifying system operative to transmit a signal from the oscillator to the speaker or other electroacoustic translating system.

The instrument comprises a simple form of audio frequency oscillator which, in one form of the invention, is tuned by changing the capacity of an inductance-capacity resonant network, while in the other form of the invention, tuning is effected by changing the inductance in the resonant circuit.

The instrument includes in its output suitable adjustable resonant circuits whereby certain bands of frequencies may be attenuated at will, and includes suitable expression control means whereby the volume of the output may readily be controlled.

Frequency generating oscillator

The frequency generating oscillator as shown in Fig. 1, comprises an electron discharge device 30 which may be a pentode of the 6J7G type, the input and output circuits of which are coupled by means of an oscillation transformer 32 having a primary 34 and a secondary 36. The pentode 30 comprises a cathode 30K, a control grid 30G1, a screen grid 30G2, a suppressor 30G3, and a plate 30P. The frequency of oscillation is determined principally by the inductive reactance of the oscillation transformer 32 and the capacitative reactance of one of the condensers CC2, CC3#, CD4, CC2#, CB3, or CD4#, depending upon which of the keys C2, C3#, D4, C2#, D3 or D4# is depressed. The keys when depressed connect the enumerated condensers to ground.

It will be understood that the last enumerated keys and condensers are representative of three or more octaves of keys, each having associated therewith a condenser. The values of these con-

densers will be so chosen that the tube 30 will oscillate at the frequency of the key associated with that condenser whenever such key is depressed.

Bias to the tube 30 is supplied by means of a grid leak R1, which is in parallel with a grid condenser C6. Screen bias to tube 30 is supplied through a voltage dropping resistor R2, and filter condenser C7. The plate load on tube 30 comprises a resistor R3 in series with winding 36 of oscillation transformer 32, as well as resistances R4 and R5. Filter condenser C8 connects the plate circuit to ground and filter resistance R6 connects it to terminal +300V of the power supply. The power supply system is not disclosed herein, but it may be of any suitable construction designed to supply the designated voltages. A power supply of the type illustrated in the copending application of Laurens Hammond and John M. Hanert, Serial No. 293,444, filed September 5, 1939, would be suitable for this purpose. The suppressor grid of tube 30 is connected to the cathode thereof.

The resistors R4 and R5 constitute a high impedance voltage divider for the output of the oscillator, which is taken from a point 38 intermediate the resistors R4 and R5, being coupled to the control grid of an amplifying triode 40 (Fig. 2), through a blocking condenser C9.

The inductance of the primary winding 34 is preferably made variable in any well known manner, as by adjustment of the amount of iron in its field, to permit tuning of the instrument to the desired pitch as may be necessary, for example, when the instrument is to be played with another instrument which cannot readily be tuned.

Vibrato apparatus

Means are provided to shift the frequency of oscillation of the oscillator tube 30 through a limited range (in the order of 3% of the frequency), at a periodicity of approximately 7 C. P. S., this means comprising an inductance L1, which is normally connected in parallel with a section of the primary winding 34 by a two-way switch 42. When it is desired to provide the vibrato, the switch 42 is shifted to complete a circuit to a contact 44, which is connected to a contact 46, the latter being adapted to make contact with the reed 48 suitably actuated to vibrate continuously at vibrato periodicity or rate. The reed 48 is connected to ground so that it effectively intermittently connects and disconnects the inductance L1 in parallel with the lowermost section of the primary winding 34 at the vibrato rate, and thus shifts the oscillator frequency through the previously mentioned range. The taps on the primary winding 34 to which the vibrato apparatus is connected, are so chosen that the means frequency of oscillation when the vibrato switch 42 is turned to "on" is the same as the frequency of oscillation when this switch is turned to "off" position.

It is to be noted that the capacitative reactance of the tuning mesh (inductance 34 and one of the condensers CC2, CC3#, etc.) is not affected by the vibrato apparatus, only the inductive reactance being altered at a periodic rate. Thus, the percentage shift in frequency for all of the notes of the instrument is the same, irrespective of the frequency at which the tube 30 is oscillating.

Output and amplifier circuits

The signal supplied to the grid of amplifier tube 40 is likewise supplied to a plurality of adjustable resonant and tone control circuits 49 shown in Fig. 2, and which may be controlled by manually operable switches 50, these switches being normally closed and opened whenever any particular one or more of the meshes 49 is to be utilized. The details of the adjustable resonant and tone control circuits may be varied considerably to provide various voicings of the instrument, one such system being disclosed more fully in the aforesaid co-pending application, Serial No. 293,444.

The amplifier tube 40, which may be a triode of the 6J5G type, is self-biased by a resistor R7 by-passed by condenser C10. The triode 40 comprises a cathode 40K, a control grid 40G, and a plate 40P. The plate circuit of this tube includes the primary of a transformer 52 which is connected to a suitable source of B supply indicated as a terminal +250V. The secondary of the transformer 52 is center tapped in the usual manner for push-pull amplification, the ends of the secondary being connected to the control grids of push-pull amplifier tubes 54, 55, which preferably are triple-grid super-control amplifier tubes of the 6K7G type. The tubes 54 and 55 respectively comprise cathodes 54K, 55K, control grids 54G1, 55G1, screen grids 54G2, 55G2, suppressor grids 54G3, 55G3 and plates 54P, 55P.

The center tap on the secondary transformer 52 has connected thereto, through a resistor R8, a mesh for expression or volume control. This mesh comprises a condenser C11, having one terminal grounded and its other terminal connected to the resistor R8 at a terminal 56, and a resistor R9 which is connected between the terminal 56 and a conductor 58. The conductor 58 is connected to a terminal +150V of the power supply system through a resistor R10 and may, upon operation of an expression control contactor 60, be connected to a terminal +100V through one or more of resistors R11 to R15 inclusive. When the expression control is shifted to its lowest volume position, it is connected to +100V through a conductor 62.

It will be understood that upon operation of the volume control lever 60, the contacts on resistor R11 to R15 inclusive, and the conductor 62, are closed sequentially in the order named, and opened in the reverse order. In so doing, they change the potential upon conductor 58 from a maximum of 150 volts to a minimum of 100 volts. The resistors R10 to R15 inclusive thus form an adjustable voltage divider circuit.

Resistor R9 and condenser C11 function to limit the rate of change of potential at terminal 56. Resistor R9 is in series with the volume control resistor mesh, being of a value large relative to the maximum resistance of said mesh, and thus serves, in conjunction with condenser C11, to cause the rate of potential change at the terminal 56 to be approximately uniform as the volume control 60 is moved from step to step. The potential at point 56 determines the grid bias applied to the control grids of the push-pull amplifier tubes 54, 55. These tubes are of the variable μ, or remote cutoff type, and advantage is taken of this feature to provide a simple expression or volume control system which will operate over a wide range such as 48 db., by varying the grid bias upon tubes 54, 55.

By making gradual the rate at which the grid bias on tubes 54, 55 changes, the expression or volume control may be simplified into a relatively small number of steps, and substantially secure a wide range of volume change without introduc-

ing undesirable sudden changes in volume, which would otherwise occur when the volume control 60 is moved from one position to another. Thus, if resistors R11 to R15 inclusive are so chosen as to provide successive 8 db. changes in volume, a 48 db. range in volume is provided with only six contacts.

The value of condenser C11 is such that the volume changes are gradual, but yet are not too slow to prevent the volume from substantially following the control lever position to produce desired rapid dynamic changes in the musical tone being rendered. The control grid bias on tubes 54, 55 is determined not only by the volume control mesh previously described, but by the potential on the cathodes of the tubes 54, 55 which, as will appear hereinafter, is determined by the operation of the keys.

The screens 54G2 and 55G2 of tubes 54, 55 are connected to a suitable terminal +250V of the power supply system, while the suppressor grids 54G3 and 55G3 thereof are connected to a conductor 64, the potential of which is determined by the depression of keys as will be described hereinafter. However, it may be stated here, that the suppressor grids are at a potential beyond cutoff whenever two or more keys are simultaneously depressed. The plates of tubes 54, 55 are supplied with current from a terminal +400V of the power supply through appropriate load resistors R16 and R17 respectively, the signals from the plates being impressed upon the control grids 66G1 and 67G1 of power output tubes 66, 67 through blocking condensers C12 and C13 respectively. The tubes 66, 67 may be of any suitable type such as 7B5 power amplifier pentodes. Grid resistors R18 and R19 are connected between the grids of tubes 66, 67 and ground, the cathodes being connected to ground through a self-bias resistor R20.

The values of the condensers C12 and C13 with respect to the values of resistors R18 and R19 are such that their time constants cannot cause appreciably long periods of cutoff for the tubes 66 and 67 because of transients occurring in the plate circuits of tubes 54 and 55, to which reference will hereinafter be made. The tubes 66, 67 are of the 6F6 type in which the suppressor grids 66G3 and 67G3 are connected to the cathodes 66K and 67K respectively within the tube structures. The screens 66G2 and 67G2 of the tubes 66 and 67 are connected to a terminal +300V of the power supply system, which is also connected to the center tap of the primary winding 68 of an output transformer 70, the secondary winding of the output transformer 70 supplying the voice coil current to a speaker 72. The terminals of the primary winding 68 are respectively connected to the plates 66P and 67P of the tubes 66 and 67.

Key operated control circuits

As previously stated, the instrument will usually comprise one or more octaves of keys which may be similar in arrangement to the keys of a piano. For the purposes of illustration herein, the instrument is assumed to have a range of three octaves, C2 to B4, and reference characters corresponding to the notes controlled have been applied to the keys illustrated in Figure 1.

Each of the keys, for example, the key C2, operates upon depression thereof successively to close three switches. The switches comprise four resilient contact arms 76, 77, 78 and 79 bearing suitable contact points. An actuator 80 engages the uppermost contact arm 76 and is adapted to press this contact arm into contacting engagement with the arm 77. Thereafter, both the arms 76 and 77 flex further to bring the arm 77 into contacting engagement with the arm 78, and still further depression of the key causes the flexing of the arms 76, 77 and 78 to bring the arm 78 into contacting engagement with the arm 79.

The arms 77 of all of the keys are connected to a common grounded conductor 82, while all of the contact arms 79 are connected to a common conductor 84. Each of the contact arms 76 is connected to the common conductor 64 through a resistor R21. In order to reduce the number of resistors R21 required for the instrument, several keys which are separated from each other by more than an octave may have their contact arms 76 connected in parallel to the same resistance R21 since it is improbable, in the normal use of the instrument, that such keys will be simultaneously depressed, since in playing a melody, interval relations of greater than an octave rarely occur.

From Figure 1, it will be noted that the switch arm 76 for the keys C2, C3# and D4 are connected to a common resistor R21, and the keys C2#, D3 and D4# are connected to a similar common resistor R21. In a similar manner, the switch arms 76 for the following groups of keys may be connected to a resistor R21, common to each of the keys of the group: D2, D3#, E4; D2#, E3, F4; E2, F3, F4#; F2, F3#, G4; F2#, G3, G4#; G2, G3#, A4; G2#, A3, A4#; A2, A3#, B4; A2#, B3; and B2, C4.

The switch arms 76 for the keys C3 and C4# may each be provided with an individual resistor R21, since they do not fit readily into any of the above groups of keys. In this way, fourteen resistors R21 may serve the purposes for which thirty-six resistors would otherwise be necessary.

As will be explained hereinafter, the purpose of a contact arm 76 and its associated resistor R21, is to prevent undesirable transients from occurring when the player, through a legato style of playing, inadvertently depresses two or more keys simultaneously.

The switch arm 78 of each of the keys is connected with its associated condenser CC2, CC3, etc., previously described, and serves, when the grounded contact arm 77 makes contact with the arm 78, to tune the oscillator 30 to the frequency corresponding with the key depressed.

It is to be noted that the control grid bias on tubes 54 and 55 is determined not only by the volume control mesh previously described, but by the potential on the conductor 88 which is determined by a voltage divider mesh consisting of resistors R22 and R23. The voltage of conductor 88 is however, not determined solely by the resistors R22 and R23, but is also changed whenever any of the switch arms 77 and 79 are connected together, and thus connect a resistor R24 in shunt with R23.

When none of the keys is depressed, the voltage on the conductor 88 is such as to bias the tubes 54, 55 substantially to cutoff, irrespective of the setting of the volume control. When, however, a key is depressed, the voltage on the conductor 88 becomes more positive because of the shunting of R24 across R23, and thus the effective bias on the grids of tubes 54, 55 decreases with resultant increase in the signal output of these tubes. The rate at which the signal increases in the outputs of these tubes is controlled mainly by the time constant of the condenser C14 and the resistor R8. At the instant that a playing key is depressed, the control grids 54G1, 55G1 of tubes 54, 55 remain at

substantially cutoff potential because condenser C14 is connected to these grids directly through the transformer secondary and not through the resistor, which might limit the rate of change of potential. However, after the key has been depressed, the transient voltage which was supplied through condenser C14 will disappear, and the bias upon the grids of tubes 54, 55 will change to their operating potential at a rate determined by R8 and C14.

When it is desired to impart a slow string-like attack to the tones produced, a condenser C15, one plate of which is connected to the mid-point of the secondary of the transformer 52, is connected by means of a switch 90 to the cathodes of tubes 54, 55. This condenser will then be in parallel with condenser C14, and thus the rate at which the operating bias is applied to the control grids 54G1 and 55G1 of tubes 54, 55 will be slower. Switch 90 may be manually operable by the player.

Upon release of the key, the rate at which tubes 54, 55 approach cut off is controlled by a condenser C16, which is in parallel with resistor R23. Resistors R22, R23 and R24 are of values chosen such that when contact arm 77 is in contact with the contact arm 79, the potential of conductor 88 is at +150 volts with respect to ground potential. When no key is depressed, resistors R22 and R23 allow the voltage on the conductor 88 to be approximately 100 volts more positive than when a key is depressed—this potential then being +250 volts. Thus, the three resistors R22, R23 and R24 constitute a voltage dividing mesh operating to determine the potential of the cathodes 54K, 55K for tubes 54, 55. It will be noted that tubes 54, 55 are connected in push-pull arrangement, so that changes in the D. C. component of the plate current in these tubes does not have any transient effect upon their signal output.

Thus, at the end of the key down-stroke, the amplifier is rendered effective to transmit the signal to the speaker, with controlled attack and decay, in so far as the supply of plate current and the control grid bias on the tubes 54 and 55 is concerned. The suppressor grids 54G3, 55G3 of these tubes are, however, maintained at a potential of substantially +400 volts, since the conductor 64 is connected through a resistor R25 with a terminal +400V of the power supply. Whenever one of the keys is depressed, the resistance R21 associated with that key, is effectively connected between the conductor 64 and ground, so that this resistance, together with the resistor R25, forms a voltage divider determining the potential upon the conductor 64, and hence upon the suppressor grids of the tubes 54, 55. Assuming that the resistor R25 has a value of 500,000 ohms, and that the resistors R21 have a value of 300,000 ohms each, the potential upon the conductor 64 or upon the suppressor grids, will change from a value of +400 volts to a value of +150 volts when only one key is depressed. If, however, two keys are simultaneously depressed, there will then be two of the resistors R21 of 300,000 ohms each forming the grounded leg of the above mentioned voltage divider. As a result, the potential on the conductor 64 will drop to 92.5 volts.

If more than two keys are simultaneously deprssed, the voltage on the conductor 64 will be correspondingly lowered. Thus, it will be seen that when one key is depressed, the potential on the suppressor grids of the tubes 54, 55 will be +150 volts, which is the same as the potential on conductor 88, which connects to the cathodes of tubes 54, 55 as previously described. Thus, when a single key is depressed, the suppressor grid is at the same potential as the cathodes of tubes 54, 55. If, through playing in a legato manner, the musician depresses two keys simultaneously, the potential of the suppressor will change from +150 volts to 92.5 volts, under which conditions the suppressor is 57.5 volts negative with respect to the cathode, which is beyond cutoff for the type 6K7G tube. The rate at which this cutoff occurs is determined by the time constant of condenser C17 with respect to resistors R25 and R21, the condenser C17 being connected between the conductor 64 and ground. The value of condenser C17 is so chosen that the rate of change of the potential will be very rapid, but not sufficiently rapid to generate objectionable transients.

The condenser C17 also controls the rate of attack of the second of two depressed keys after the first key has been released. These decay and attack rates are made clickless so as to provide a musically satisfactory transition from one note to the other as one of the two keys is released.

Operation

The instrument is played in the usual manner of a melody instrument, by successively depressing the desired keys, C2 to B4, the musician preselecting the desired quality of tone by opening one or more of the switches 50, and controlling the intensity of the sound produced by moving the volume control 60. The musician may preselect the desired rate of attack by operation of the switch 90, and if a vibrato is desired in the tones produced, the vibrator switch 42 is operated to make contact with the switch contact 44.

Having thus operated these various controls to condition the instrument to produce the tones desired, or suitable for the rendition of the particular musical selection, the instrument is played preferably in a legato organ-like manner. Upon the initial portion of the down-stroke of any key, for example the key C2, the potential on the conconductor 64 will be lowered as previously described to +150 volts. Further depression of the key will cause the grounded arm 77 to engage the arm 78, thus connecting the associated tuning condenser CC2 in parallel with the primary 34 of transformer 32, thereby to tune the oscillator to the frequency of the note C2.

It will be understood that the oscillator tube 30 and its associated circuits will substantially instantaneously shift to the frequency determined by the condenser CC2, although such shift in frequency may be accompanied by undesirable transients. As will appear hereinafter, the amplifier is paralyzed to prevent the transmission of such transients to the speaker.

Further depression of the key C2 causes its switch arm 78 to contact with the switch arm 79, thus effectively connecting the switch arm 79 to the grounded conductor 82 through switch arm 77. Connecting the switch arm 79 to ground causes the resistance R24 to be placed in shunt with the resistance R23, thereby lowering the voltage on the conductor 88 which is connected to the cathodes 54K, 55K of the tubes 54, 55, the rate at which the change in the potential taeks place being determined principally by condenser C14, and by the condenser C15 if the switch 90 is closed.

As the potential of the cathodes of the tubes 54, 55 is thus shifted to a lower value by an amount of 100 volts, the potentials on the control grids 54G1, 55G1 of tubes 54, 55 are raised relative to the cathodes, to render these tubes conducting, at a rate determined principally by the condensers C14 and C15 and resistance R8, as previously described. The oscillations generated by the tube 30 are thus transmitted through the amplifier tube 40, push-pull amplifier tubes 54, 55 and power tubes 66 and 67 to the speaker.

The gain of the tubes 54, 55 may of course be varied as desired by the player through operation of the volume control 60, which changes the potential of the terminal 56 at a gradual rate because of the condenser C11, as prevoiusly described, and thus determines the effective bias on the control grids 54G1, 55G1 of tubes 54, 55, after the transient conducted through condensers C14 and C15 to the mid-point of the secondary of the transformer 52 has subsided.

If two keys, for example, keys C2 and C2#, are simultaneously depressed, the potential upon conductor 64 will be lowered to a value of 92.5 volts, as previously described, since there will then be two resistances R21 connecting this conductor to ground. Under these circumstances, as previously pointed out, the potential of the suppressor grids 54G3, 55G3 will be 57.5 volts negative with respect to the cathodes 54K, 55K, which will cut off the electron stream to the plates 54P, 55P, thus rendering tubes 54, 55 ineffective to transmit the signal. This is desirable because upon the simultaneous depression of two or more keys, two or more condensers CC2, CC2#, etc., will be connected in parallel and tune the oscillator to a frequency which will not be at the frequency corresponding to either of the keys depressed.

Since the contact arms 76 will contact with the arms 77 before the tuning condensers are connected in the tuning circuit, the amplifier will be substantially paralyzed by the time that the second contact is made by the second depressed key, as previously described. Thus, the signal of undesired frequency, together with the transient due to shift in frequency of the oscillator, because of the insertion in the tuning circuit of a second tuning condenser, is prevented from being heard in the speaker of the instrument. Also, upon depression of the second key while the first was depressed, the signal controlled by the first key decays at a non-objectionable transient producing rate because of the provision of the condenser C17, which limits the rate of change of potential on the suppressor grids 54G3, 55G3 of the push-pull tubes 54, 55.

Upon release of one of two keys simultaneously depressed, the oscillator will first be shifted in frequency to that determined by the condenser associated with the key held depressed, and thereafter, the potential on the suppressor grids of the tubes 54, 55 will return at a non-transient producing rate to the +150 volt potential, which is its normal operating potential, and the same as that upon the cathodes 54K, 55K of the tubes 54, 55.

Since the instrument becomes silent whenever two keys are held depressed at the same time, the player will find that to obtain a substantially legato style of playing, the second key should be depressed as soon after the release of the first key as possible. On the other hand, to produce a staccato effect, no special technique is required since this effect may be obtained by playing the instrument with the usual staccato-detached touch, or may be obtained by playing it with an extreme legato touch, such that two keys are frequently depressed simultaneously for short intervals.

Modified form of oscillator tuning

Figure 3, taken in conjunction with Figure 2, discloses a modified form of the invention in which the oscillator is tuned by changing the inductance of its resonant circuit instead of changing the capacity in the circuit, as in the instrument previously described. All of the parts, with the exception of the oscillator tuning circuits and the vibrato apparatus, are identical with those previously described, and the same reference characters have therefore been applied to the elements of Figure 3, as have been used in describing the corresponding elements of Figure 1.

The resonant circuit for the oscillator 30, as shown in Figure 3, comprises a primary winding 100 of a transformer having a secondary 36. The winding 100 is provided with a plurality of taps (thirty-six in number for a three octave instrument), which are at such points along the winding as will cause the oscillator to generate frequencies of the notes of the musical scale, when one of these points is connected to ground. The capacity of the resonant circuit for tuning the oscillator comprises a condenser C30 which is shunted by a small trimmer condenser C31, for tuning purposes, and by a condenser C32, when a vibrato control switch 102 is in the position shown in Fig. 3. When the switch is moved to its opposite position, it connects with a condenser C34, the other terminal of which is periodically connected to ground by a reed 48 of the vibrato apparatus. The value of the condenser C32 is such as to cause oscillation at a pitch which is the mean of the two extreme pitches produced when the vibrato apparatus is in use.

The various taps on the primary winding 100 are connected by suitable conductors to the switch contact arms 78 of the various keys. Thus, upon depression of a key, such for example as the key C2, the inductance effective to determine the frequency of the oscillator consists of that portion of the winding 100 which is between the tap to which the switch arm 78 of the key C2 is connected and a terminal 104.

The oscillator tuning and keying circuits shown in Figure 3 are made with a minimum number of parts, since the individual capacities for each of the notes required in the form of the invention shown in Figure 1, are replaced by the single primary winding 100 provided with the necessary taps, which winding can be produced at relatively low cost. The instrument is played in the same manner as previously described with reference to Figures 1 and 2, and the musical results obtainable are identical with those previously described.

When two or more keys are simultaneously depressed, it will be apparent that some turns of the primary winding 100 will be short-circuited through the key switch circuits, thus, introducing losses in the transformer 32, which may cause cessation of oscillation or the production of spurious frequencies. However, such transition frequencies and interruption in the oscillation of the tube 30 are not discernible, because while they are taking place, the amplifier is paralyzed by virtue of the utilization of resistors R21, and the suppressor biasing circuit elements associ-

ated therewith, which operate in the manner previously described.

A further function of the resistors R21 and their associated circuits is to prevent transmission to the loud speaker of undesirable transients incident to making and breaking the key operated switch contacts in the tuning circuit of the oscillator. Thus, even though the tuning circuit of the oscillator were arranged so that simultaneous depression of two keys would not result in a spurious frequency, there would still be considerable advantage in using the resistors R21 and their associated circuits, because of the fact that the latter circuits would be effective to prevent the transmission of key clicks or key noises to the loud speaker.

While I have shown and described particular embodiments of my invention, it will be understood that the invention as illustrated and described is merely exemplary, and that I desire to include within the scope of my invention, defined by the following claims, all such similar and modified forms of the invention by which substantially the results of my invention may be obtained through the use of substantially the same or equivalent means.

I claim:

1. In an electrical musical instrument of the melody type, in which a signal frequency generator is adjusted to supply any one of a plurality of frequencies, and in which the output of the generator is controlled by an electron discharge device having a control grid receiving a signal from the generator and a second grid effective to cut off the electron stream through the discharge device; the combination of a voltage controlling network connected to the second grid of the discharge device to determine the potential thereof, and means operated only upon depression of two or more of the keys of the instrument to change the potential on said second grid to a value which cuts off the electron stream through the electron discharge device, said means being rendered effective by changing an impedance in a part of said voltage controlling network.

2. In an electrical musical instrument of the melody type having a plurality of keys, the combination of an adjustable generator of electrical impulses of musical frequency, key controlled means to adjust the frequency of said generator, an output circuit including an electron discharge device having a control grid and a second grid capable of cutting off the electron stream through said device upon having a predetermined potential impressed thereon, means for normally maintaining the potential on said second grid at a value which will permit substantially unimpeded flow of electrons through said device, and means operated by the keys to change the potential on said second grid to a value sufficient to cut off the electron stream to said device, said last named means being operative whenever two or more keys are simultaneously depressed and being inoperative when but a single key is depressed.

3. In an electrical musical instrument having a tunable generator of electrical impulses of musical frequency, key controlled means for tuning said generator to any one of a plurality of musical frequencies, an output circuit for said generator, said output circuit including an electron discharge device having a cathode, a control grid, a suppressor grid, and a plate, means for normally maintaining a potential on said suppressor grid such that the latter does not appreciably affect the electron stream through said device, and means operable upon the simultaneous depression of two or more keys to change the potential on said suppressor grid to a value at which said suppressor grid will cut off the electron stream through said device whereby, when a plurality of keys are simultaneously depressed, said electron discharge device will be effective to stop transmission of electrical impulses from said generator.

4. In an electrical musical instrument, the combination of an oscillatory generator of musical frequency, an output circuit for said generator comprising a signal amplitude controlling electron discharge device having a plurality of grids including a suppressor grid, a plurality of depressible keys, a plurality of circuits successively completed upon depression of each of said keys, and voltage divider means effective upon the completion of the first circuits associated with two or more keys to change the potential upon the suppressor grid of said electron discharge device to a value at which it cuts off the electron stream therethrough.

5. In an electrical musical instrument having a plurality of keys, an oscillator, means controlled by said keys for selectively tuning said oscillator to frequencies corresponding to notes of the musical scale, an electron discharge device having at least two grids, means for impressing the signal produced by said oscillator upon one of said grids, a voltage controlling circuit for determining the potential on the other of said grids, said circuit including a plurality of impedance elements capable of changing the voltage impressed upon said other grid, said impedance elements being of such value that when more than one of them is connected in said circuit, the voltage impressed upon said other grid will be sufficient to cut off the electron stream through said electron discharge device, and means operated by each of said keys to connect one of said impedance elements in said voltage controlling circuit upon the initial portion of the down-stroke of the key, whereby said electron discharge device will be cut off whenever two or more keys are simultaneously depressed.

6. In an electrical musical instrument of the melody type having a generating system, an output system receiving signals from the generating system for amplification and translation into sound, having a plurality of keys, and in which the simultaneous depression of two or more keys may result in the generation of undesired frequencies by said generating system; the combination of an output circuit element the potential of which determines whether said output circuit shall be effective to transmit signals from said generating system, means for normally maintaining said element at a potential which renders said output circuit effective, and means operated by said keys for changing the potential on said element in a sense toward rendering said output circuit ineffective, said potential changing means being of such value that the depression of more than one key will be required to change the potential on said element to a value rendering said output circuit ineffective.

7. In an electrical musical instrument, the combination of a plurality of keys, a plurality of switches associated with each key and arranged to be sequentially operated upon the depression thereof, an output circuit including an electron discharge device having a suppressor grid, a voltage controlling network connected to said sup-

pressor grid, an impedance element forming part of said network, a circuit completed by the first of said sequentially operated switches to connect said impedance element in said network in a manner to lower the potential impressed on said suppressor grid, an adjustable frequency oscillator, and a circuit completed by the closure of another of said switches to tune said oscillator to the note frequency represented by the depressed key.

8. In an electrical musical instrument having an adjustable frequency generator and an output circuit, an element in said output circuit, the potential of which determines whether a signal will be transmitted by said circuit, a network determining the potential of said element, a plurality of key operated switches, and means including a potential source and circuits controlled by said switches and associated with said network to change the potential of said element in a direction to prevent the transmission of a signal by said output circuit, the potential change effected by completion of one of said circuits upon operation of one of said switches being insufficient to prevent transmission of the signal, but the potential change effected by the concurrent completion of two or more of said circuits by said switches being sufficient to prevent transmission of the signal.

9. In an electrical musical instrument having an adjustable frequency generator and an output circuit, said output circuit having an element the potential of which is a factor in determining the amplitude of the signal transmitted by said circuit, a source of potential of such value with respect to a fixed potential that when applied to said element it will cause transmission of the signal by said circuit, a resistor connecting said source to said element, a plurality of keys, switches operated thereby, a conductor maintained at said fixed potential, connections from said conductor to poles of said switches, and resistances connecting other poles of said switches to said element, said resistances being of such value relative to the parameters of said element and relative to the values of said potential source and resistor that connection of one of said resistances to said conductor will not cause said element to prevent transmission of the signal, but the connection of two or more resistances to said conductor will cause said element to prevent transmission of the signal by said output circuit.

10. In an electrical musical instrument having an output circuit, the combination of an electron discharge device having a cathode, grid and plate, circuits connected to said device to cause oscillation thereof, said circuits including a condenser effectively connected between said grid and said cathode, a tapped tuning inductance having one terminal thereof connected to said grid, and a plurality of key operated switches effective respectively to connect the taps of said inductance to said cathode, thereby to change the frequency of oscillation of said device to the frequencies of the notes of the musical scale upon closing the key operated switches.

11. In an electrical musical instrument, the combination of an electron discharge tube oscillator having a tuning circuit including a condenser and a tapped inductance, an output apparatus therefor including an amplifier and electroacoustic translating means, a plurality of manually operable playing keys, at least two switches operated by each of said keys, connections respectively between the taps on said inductance and one of the switches of each of said keys for rendering effective in said tuning circuit a predetermined number of turns of said inductance depending upon the particular key which is operated, and a circuit completed by the second of each of said key operated switches to render said amplifier effective to transmit signals from the oscillator to the electroacoustic translating means.

12. In an electrical musical instrument having an output circuit, an element in said output circuit the potential of which determines whether the output circuit will be operative, means including a potential source connected to said element through a resistance for normally maintaining said element at a potential numerically greater than that required to render said output circuit operative, a plurality of key operated switches, and a plurality of current flow limiting circuits including said element and completed respectively by said switches to reduce numerically the potential on said element, said circuits having such current flow limiting characteristics that the completion of at least two circuits is required to reduce the potential on said element to a value sufficiently low to render said output circuit inoperative.

13. In an electrical musical instrument having an output circuit, an output circuit paralyzing element the paralyzing effect of which is dependent upon the potential impressed on said element, relatively high impedance means normally maintaining a non-paralyzing potential on said element, a plurality of keys, a potential source, and relatively lower impedance circuits including said source and said element completed upon the depression of said keys respectively to change the potential on said means to a paralyzing value whenever two or more of said keys are depressed at the same time.

14. In an electrical musical instrument, the combination of an electrical tone signal generator of variable frequency, a signal output circuit for said generator including an electron discharge device having a plurality of electrodes the relative potentials of which determine the signal amplitude, a plurality of playing keys, three switches associated with each of said keys and operable successively by depression of the key, circuits completed by said switches respectively, one of said circuits including means effective to change the relative potentials on two of said electrodes toward cut off value to an extent such that completion of a second such circuit upon contemporaneous depression of another key will cause the relative potentials on said electrodes to exceed cutoff value, another of said circuits including means for determining the frequency of the signal supplied by said generator, and the circuit completed by the last operated of said switches including a pair of said electrodes and means controlling their relative potentials to determine the intensity envelope of the tone signal transmitted by said device.

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