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ELECTRICAL MUSICAL INSTRUMENT

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2 SHEETS—SHEET 1

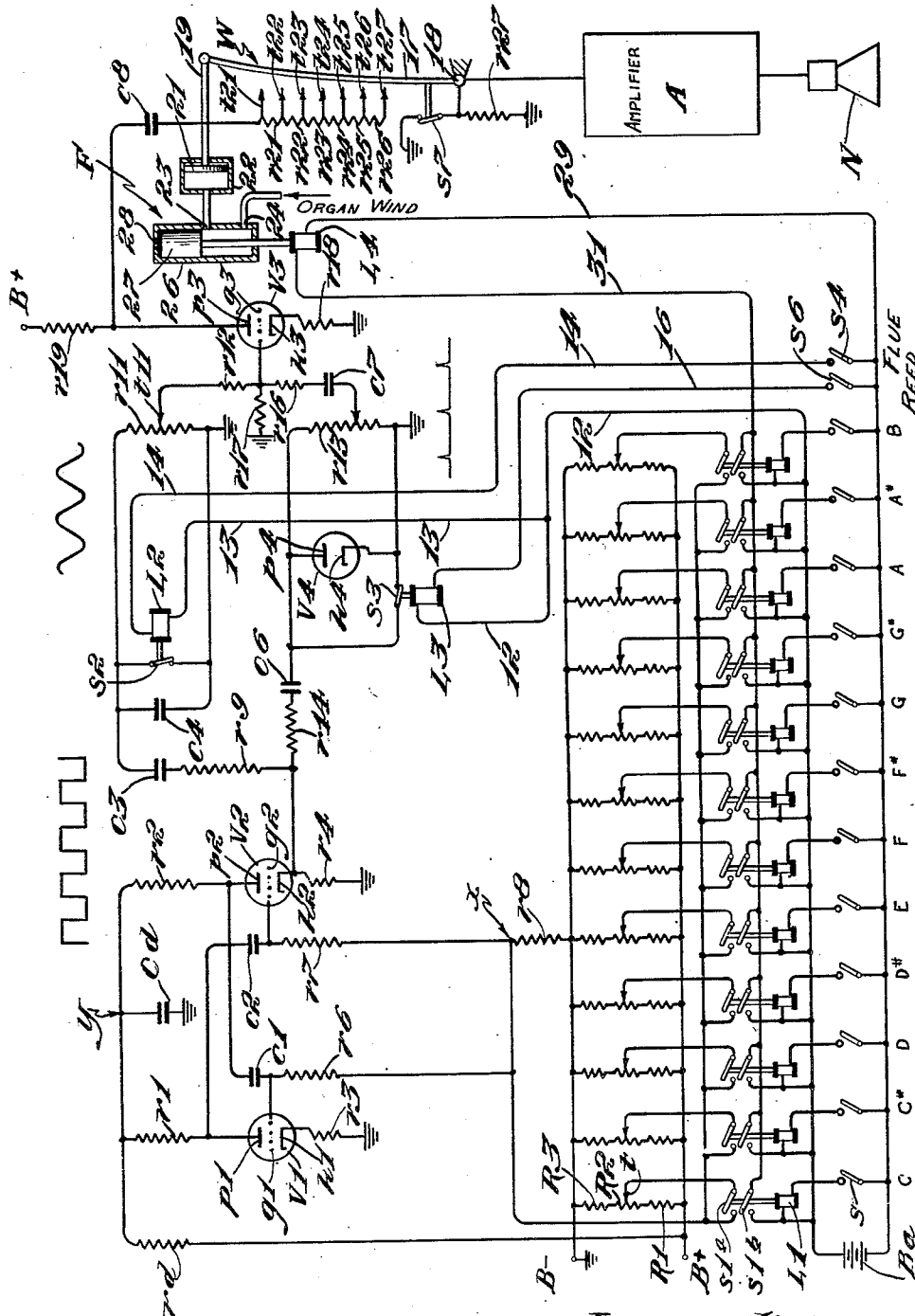
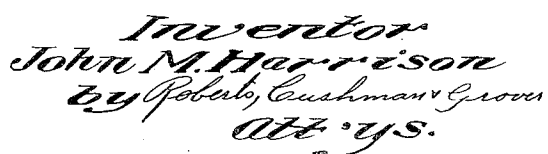


Fig. 1

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ELECTRICAL MUSICAL INSTRUMENT

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In the art of organ building some of the most difficult problems encountered are related to the design and erection of the bass pipes. Because of their large size, such pipes are expensive and awkward to install. When available space is limited they cannot be used at all, or it may become necessary to offset them which further adds to the expense of the organ.

Objects of this invention are to provide a musical instrument with an acoustical system which simulates with fidelity the tone, frequency, rate of attack and short term drift of bass organ pipes, which eliminates the necessity of using such large pipes in organs of highest quality, which is less subject to long term frequency drift than such pipes, which can be operated from the usual manual and pedal keyboards and stops of an organ, which provides for independent tuning of each of the respective notes, which is small in size, which is economical to construct and to install, and which advances the art of organ building generally.

In a broad aspect the invention contemplates an electrical instrument for simulating the tones of an organ comprising a vacuum tube audio frequency oscillator which is tuned to the frequency of the desired notes of the chromatic musical scale by resistor means such as selectively interposing a network of resistors between the vacuum tube control electrode and a direct power supply. In this manner the potential impressed upon the control electrodes determines the resonating frequency of the oscillator. The output of the oscillator is coupled to an acoustical reproducer by means of an output network which includes an amplifier.

In another aspect the output network also includes a filter for modifying the shape of the output wave of the oscillator so that the acoustical output of the coupled reproducer more nearly simulates the tones of the organ. Such tone simulation may be further improved according to the invention, by incorporating in the output network an articulator for gradually increasing the magnitude of the signal from the oscillator as it is supplied to the reproducer.

An important feature of the invention is the incorporation in the circuit between the vacuum tube anode and the power supply of a series impedance and a shunting impedance connected in series between the terminals of the power supply thereby introducing a time delay in the frequency changes of the oscillator which delay simulates the initial drift of an organ pipe.

In a specific aspect the invention contemplates

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a musical instrument for simulating the bass tones of an organ, comprising a direct power supply circuit which includes a shunting drift capacitor and a series resistor connected in series between the terminals of the power supply. The anodes of the two vacuum tubes of an audio frequency oscillator are connected to the junction of the drift capacitor and the series resistor so that power is supplied to the anodes through the resistor. The anode of each tube is also capacitance coupled to the control electrode of the other tube. The potential upon the tube control electrodes and therefore the resonating frequency of the oscillator is controlled by a plurality of resistor groups to produce frequencies corresponding to the notes of the chromatic scale, each of the resistor groups being selectively interposed between the control electrodes and the power supply circuit by means of a respective key-operated switch.

The oscillator output is coupled to one or more acoustical reproducers by means of an output network including at least one amplifier, a reed filter and a flue filter. These filters are controlled by selectively connecting their respective outputs to ground by means of switches operated by the respective stops of the organ. The reed filter comprises a shunt resistor and a capacitor connected in series therewith. A rectifier is connected in parallel with the shunt resistor. The time constant of the filter is made short relatively to the frequency of the oscillator so that the filter output consists of a series of short unidirectional pulses. The flue filter comprises a capacitor in series with a resistor which resistor is also connected in parallel with a shunting capacitor so that the higher oscillator frequencies are attenuated thereby. The connection between the oscillator and the reproducer is completed by an articulator having a moving contact which is actuated by a pneumatic device progressively to decrease the number of resistors connected between the oscillator and the reproducer.

These and other objects and aspects will be apparent from the following description of an illustrative specific embodiment of the invention referring to drawings in which:

Fig. 1 is a circuit diagram of this specific embodiment;

Fig. 2 is an elevation view in partial cross-section showing an articulator and control valve;

Fig. 3 is a plan view of the articulator shown in Fig. 2;

Fig. 4 is a cross-sectional view on line 4—4 of Fig. 3 showing one type of moving contact; and

Fig. 5 is a cross-sectional view on line 4—4 of Fig. 3 showing a second type of moving contact.

The particular embodiment of the invention to be described is used to replace the twelve 32-foot pipes of the bass register of a conventional pipe organ and is operated conjointly with the other pipes in the usual manner by means of the key-boards and stops of the organ.

The electrical diagram of this instrument is shown in Fig. 1, wherein the vacuum tubes V1 and V2 are capacitance coupled as an audio frequency oscillator of the multivibrator type. Such coupling is accomplished by linking the control electrode *g1* of the tube V1 with the anode *p2* of the tube V2 by means of a coupling capacitor C1. A capacitor C2 couples a control electrode *g2* to the anode *p1* in an analogous manner. Direct power is supplied to the oscillator by means of a circuit including a common series impedance such as the resistor *rd* and the resistors *r1* and *r2* which connect the anodes *p1* and *p2* respectively with the positive terminal B+ of a direct power supply (not shown). The negative terminal B- of the power supply is grounded in the conventional manner. A shunt impedance *Cd* whose function will be described in detail hereinafter, is connected from the common junction *y* of the resistors *rd*, *r1* and *r2* to ground. To supply a biasing potential for the tubes V1 and V2, the cathodes *k1* and *k2* thereof are grounded through the resistors *r3* and *r4* respectively.

The frequency of the above described oscillator is the function of the potentials applied to its respective electrodes. By using a direct power source, voltage stabilized by a glow tube or in any of the other well-known means, the potential upon the anodes *p1* and *p2* is maintained substantially constant and the oscillator tuned to the desired output frequency by variations of the potential upon the control electrodes *g1* and *g2*. In the embodiment illustrated, this control electrode potential is obtained by linking the control electrodes *g1* and *g2* to the direct power supply by means of an adjustable resistor network. The control electrodes *g1* and *g2* are connected to the common point *x* by the resistors *r6* and *r7* respectively. During standby conditions when no note is being played, the point *x* and therefore the control electrodes *g1* and *g2* are maintained at a definite potential by coupling the point *x* to the B- terminal of the direct power supply by means of a resistor *r8*.

The control electrode potentials corresponding to frequencies of the respective notes of the chromatic scale are obtained from the voltage drops occurring across portions of preselective combinations of resistors of the resistor network which are connected in series across the direct power supply. For example, the potential corresponding to the frequency of the note "C" is taken from the adjustable tap *t* of a central resistor R2 of the combination R1, R2 and R3 which are in series between the terminals B+ and B-.

This potential tapped from resistor R2 is impressed upon the point *x* and thus upon the control electrodes *g1* and *g2* by the closing of the contacts *s1a* by the energization of an operating solenoid L1. The solenoid L1 is energized from a low potential source such as the battery Ba or from the low tension potential supply of the organ by means of the switch *s* which is operated by a conventional key or pedal of the organ manual. The energization of the solenoid L1

also conjointly closes contacts *s1b*, whose function will be discussed in detail hereinafter.

The oscillator output frequencies corresponding to the remaining notes of the 32-foot pedal section of the organ are obtained in an analogous manner by connecting by means of key operated switches the proper potential obtained from respective preselected resistor combinations. Only the twelve notes of the 32-foot pedal section are illustrated, but it is possible by proper resistor combinations to extend the range of the instrument to approximately twenty semi-tones. Although the long term frequency drift has been found to be less than that of large organ pipes, the adjustable tap *t* of the resistor R2 and corresponding resistors of the other resistor combinations provide the means for independently tuning the separate note frequencies.

The capacitor *Cd* connected in the anode power supply circuit as described above provides a means for simulating the initial drift in the frequency of a bass organ pipe as it first commences to sound upon the depressing of the corresponding key. As the resistors *r1* and *r2* in series with the anodes *p1* and *p2* respectively are connected to the direct power supply by the resistor *rd*, the effective voltage of the power supply to the oscillator under steady conditions of oscillation is that of point *y*, the common junction of the resistors *rd*, *r1* and *r2*. As the oscillator is tuned by varying the control electrode potentials, the anode circuit current and therefore its potential is a function of whether or not a key has been depressed and to a lesser extent which note has been sounded. The electrical storage capacity of the capacitor *Cd* is made great enough so that whenever the control electrode potentials are varied the potential supplied to the anodes *p1* and *p2* tends to remain constant and only slowly drifts to the potential determined by the voltage drop across the resistor *rd* corresponding to the anode current. The oscillator frequency being a function of the anode potentials, the oscillator frequency also drifts slowly to a terminal frequency determined by the potential of the control electrodes thereby more clearly simulating the short term drift of a bass pipe.

The output of an oscillator is taken off across the cathode resistor *r4* of the tube V2 as such output has substantially a square wave shape which will with simple filtering supply tones that adequately represent the octave of the flue organ pipes of the 32-foot pitch. Furthermore, at this point the "generator impedance" of the oscillator is low and changes in impedance of the following filter stages have a relatively small effect upon the frequency and output of the oscillator.

Two filters are shown in Fig. 1, the first filter having an output simulating the flue stop; the other filter simulating the reed stop of an organ. The flue filter comprises a series impedance such as the capacitor C3, one plate of which is coupled to the cathode *k2* by a resistor *r9*, the other plate being grounded through a tapped resistor *r11*. Connected in parallel with the resistor *r11* are a shunt impedance such as the capacitor C4 and the normally closed contacts *s2* operated by the solenoid L2. The combined action of the resistor *r11* and the capacitors C3 and C4 attenuates the higher frequency harmonics in a manner similar to that which a conventional tone control operates. The filter output is taken off by a variable tap *t11* of the resistor *r11* which is coupled to the control electrode *g3* of an amplifier vacuum tube V3 by a resistor *r12*.

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With the solenoid L2 deenergized the contacts s2 are closed to shunt the upper end of the resistor r11 to ground so that no potential appears upon the control electrode g3. The resistors r9 and r12 act as buffers to prevent such shunting action from influencing either the other filter circuit connected to the control electrode g3 or the frequency of the oscillator.

The solenoid L2 is energized to open the shunting contacts s2 by means of a circuit including the battery Ba, the wires 12, 13 and 14 and a switch s4 operated by drawing the flue stop of the organ.

The reed filter comprises a shunt resistor r13 and series impedance such as the capacitor C6 which is coupled to the cathode k2 of the oscillator by a buffer resistor r14. A rectifier such as the diode vacuum tube V4 and the normally closed contacts s3 are connected in parallel with the resistor r13. The tube V4 is oriented so that the anode p4 and the cathode k4 are connected respectively to the ungrounded and grounded ends of the resistor r13. The filter output is impressed upon the control electrodes g3 of the tube V3 by means of a series circuit including an adjustable tap t13 of the resistor r13, a coupling capacitor C7 and a buffer resistor r16.

The reed filter is turned off and on in a manner analogous to that described above in connection with the flue filter by the closing and the opening of the contacts s3 by means of a solenoid L3 which is energized from the battery Ba. The closing of a switch s6 operated by the reed stop completes an energizing circuit through the wires 12 and 16. It will be noted that both filters are at all times connected to both the oscillator and the control electrodes g3 so that they can be used as desired either independently or conjointly by the proper manipulation of the organ stops.

The control electrode g3 and the cathode k3 of the tube V3 are connected to ground in the usual manner by the resistors r17 and r18 respectively. The circuit of the anode p3 branches to connect with the positive terminal B+ of the direct power supply through a series resistor r19 and to the input of an amplifier A by means of a capacitor C8 and an articulator W. The output of the amplifier A is connected to one or more acoustical reproducers such as the loud speaker N. The amplifier A and the acoustical reproducer N are conventional in design, but must pass frequencies as low as 30 cps. to simulate satisfactorily the tones of the low notes.

An articulator W is used to reduce gradually an ohmic impedance inserted between the amplifier tube V3 and the amplifier A by successively making with a plurality of contacts t21, t22, t23, t24, t25, t26 and t27 which are linked with the respective terminals of the series resistors r21-r26. The articulator W comprises a moving contact such as the elastic contact bar 17, which is coupled to the input of amplifier A, is positioned so that to make successively with the contacts t21-t27. One end of the bar 17 is held stationary at a point 18. The other end of the bar 17 is pivotally joined to one end of a connecting rod 19. The opposite end of the rod 19 is fastened to a pneumatic piston 21 which moves within the cylinder 22. With a plunger 27 of a control valve F in the upper position shown, air to operate the piston 21 against the elastic restoring force of the bar 17 is supplied from the organ wind supply through the ports 23 and 24 in the valve casing 26. The valve plunger 27 is moved upon the energization of solenoid L4 to close the

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organ wind supply port 24 and to connect the cylinder 22 to atmospheric pressure through the port 23 and an exhaust port 28 in the top end of the casing 26.

The solenoid L4 is connected to the low tension potential supply battery Ba by a circuit including the conductors 29 and 31 and the contacts s1b which are closed as described heretofore by the energization of the solenoid L1 upon the closing of the key-operated switch s. It will be noted that the closing of any of the other key-operated switches corresponding to the switch s will, in an analogous manner, close the respective contacts in parallel with the contacts s1b to complete a circuit energizing the solenoid L4.

Whenever the operating of any key connects the cylinder 22 to atmospheric pressure as described above, the force exerted by the piston 21 which distorts the contact bar 17 is removed. Because of the small area of the exhaust port 28, the pressure within the cylinder 22 slowly falls so that the restoration of the bar 17 first opens a switch s7 and then successfully makes with the contacts t27-t22 until t21 is connected whereupon the amplifier A is directly linked to the anode p3 by means of the capacitor C8.

In the table below are given the characteristics of the circuit elements connected as described above to comprise an instrument which has been found to simulate very closely the tones of the twelve notes of the 16 foot pipes of an organ.

Tuning resistors for 150 volt direct power supply

Note	R1	R2	R3
C-----	120K	15K	51K
C#-----	100K	15K	51K
D-----	92K	15K	51K
D#-----	82K	15K	51K
E-----	82K	15K	40K
F-----	100K	15K	110K
F#-----	100K	15K	110K
G-----	73K	15K	100K
G#-----	62K	15K	110K
A-----	50K	15K	100K
A#-----	40K	15K	110K
B-----	40K	15K	130K

Tubes

V1-6J5 V3-6H6
V2-6J5 V4-6C5

Capacitors

Cd-4mfd. C4-0.01 mfd.
C1-0.05 mfd. C6-0.001 mfd.
C2-0.05 mfd. C7-0.25 mfd.
C3-0.05 mfd. C8-0.5 mfd.

Resistors

rd-20K r14-0.5M
r1-30K r16-1M
r2-30K r17-1M
r3-5K r18-5K
r4-5K r19-50K
r6-1M r21-200K
r7-0.5M r22-350K
r8-1M r23-600K
r9-0.5M r24-1M
r11-1M r25-1.75M
r12-1M r26-3M
r13-1M r27-200K

In Fig. 2 are shown the details of the second embodiment of an articulator W1 which performs the same function as the articulator W described above. The articulator W1 comprises a hollow air chamber 32 with a cover 33 having one side fastened to the chamber 32 by means of

a hinge 34. A flexible bellows 36 maintains an airtight joint between the chamber 32 and its cover 33. Three screws 37 fasten one end of a moving contact such as the contact plate 38 to the top of the chamber cover 33. The other end 39 of the plate 38 is bent at an angle so that it will make with the contacts $t21-t27$. These contacts are formed by a plurality of flexible conductors each having one end molded in a plastic block 41 and connected to a respective binding post 42 so that a series of parallel cantilever springs is formed. The resistors $r21-r26$ (Fig. 1) are connected between adjacent binding posts 42.

Also molded in the block 41 are two additional spring $s7a$ and $s7b$ which comprise the movable and stationary contacts respectively of the switch $s7$. The end of contact $s7b$ is bent at right angles so that it makes with contact $s7a$ when the latter contact is in its normal position thereby to connect the input of the amplifier A to ground.

As is shown in Fig. 4, the contacts $t21$ through $t27$ can be arranged in a horizontal plane and the edge of the end 39 of the contact plate 38 skewed so that upon the deflation of the bellows 36, the plate descends to make successively with the contacts $t27$ through $t21$. The broken line 39' illustrates one position of the edge of the plate end 39 during its descent wherein the edge is about to make with the contact $t25$ after having successively moved the contact $s7a$ to the position $s7a'$ to open the switch $s7$ and deflected the contact $t27$ to the position shown at $t'27$.

In Fig. 5 is shown another embodiment wherein the edge of the contacting plate 39a is horizontal and the contacts $t21a$ through $t27a$ are arranged in a skewed plane. The broken line 39a, illustrates one descending position of the edge of end 39a wherein the contacts $s7a$ and $t27a$ have been deflected to the positions shown at $s7a$ and $t'27a$ respectively.

Air is supplied to the articulator W1 from the organ wind supply through the solenoid operated valve F1 and the tubes 43 and 44. The valve F1 comprises a solenoid chamber 46 wherein are located the series connected operating solenoids $L4a$ and $L4b$. The upper end of the solenoid pole pieces 47a and 47b are linked by a strap 48 of low reluctance material. The opposite ends of the pole pieces 47a and 47b project through a barrier wall 49 of non-magnetic material which separates the solenoid chamber 46 from a valve chamber 50. Within the valve chamber 50 is located a valve plate 51 which rests upon the floor of the valve chamber 50 to cover a bleeder port 52 when the solenoid $L4a$ and $L4b$ are de-energized. The plate 51 is made of magnetic material so that it is attracted by the energization of the solenoids $L4a$ and $L4b$ to block off the inlet port 53 located between the solenoids and extending through the barrier wall 49 from the solenoid chamber 46 to the valve chamber 50.

An orifice 54 joins the valve chamber 50 to a plenum chamber 56 which is also connected with the articulator W1 by the tube 44. By use of the plenum chamber 56 the effective volume of the articulator chamber 32 is increased and the size of the orifice 54 and the bleeder port 51 may be increased for any specific articulator operating rate.

The articulator operating rate is made adjustable by the use of a needle valve 57 which is threaded into a valve bonnet 58 attached to the bottom of the outside of the valve chamber 50 so that the point of the valve 57 projects into the bleeder port 52 thereby to reduce the effective

area thereof. The valve 57 is threaded into the bonnet 58 so that turning the valve changes the effective bleeder port area.

The instrument is operated in a manner similar to that in which the conventional pipe octaves of an organ are played. For example, if the flue stop is drawn, the switch $s4$ is closed to energize the solenoid $L2$ from the battery Ba . The resultant opening of the normally closed contacts $s2$ thereby removes the grounding shunt from the output of the flue filter. The shunt across the output of the reed filter is removed in an analogous manner by opening the contacts $s3$ upon the closing of the switch $s6$ by the drawing of the reed stops. Either stop or both may be drawn concomitantly as required. It will be noted that the operation of the stops does not result in any output from the reproducer N because of the grounding of the input of the amplifier A by the switch $s7$ and the open circuit in the articulator W.

Upon the depressing, for example, of the key of "C," the key-operated switch s is closed to connect the solenoid $L1$ to the battery Bz . The resultant energization of the solenoid $L1$ has two effects. First, the closing of the contacts $s1a$ impresses the proper potential obtained from the drop in the resistors $R1$, $R2$ and $R3$ upon the control electrodes $g1$ and $g2$ to obtain an oscillator output with a frequency which slowly drifts because of the above described action of the capacitor Cd to correspond to the frequency of the key of "C." The oscillator output is modified by either or both of the filters in a manner described heretofore, and the filter output impressed upon the resistors $r21-r26$ after being amplified by the tube $V3$.

Second, the energization of the solenoid $L1$ conjointly closes the contacts $s1b$ thereby completing the circuit through wires 29 and 31 to energize the solenoid $L4$ (or $L4a$ and $L4b$). Upon the opening of the port 28 (or 52), the air pressure in the cylinder 22 (or the chamber 32) gradually reduces to atmospheric pressure. The resultant movement of the piston 21 (or the bellows 36) operates the bar 17 (or the plate 38) so that the switch $s7$ is opened to remove the ground from the input of the amplifier A. The continued operation of the bar 17 (or plate 38) successively connects the input of the amplifier A to the contacts $t27-t21$ to gradually decrease the ohmic impedance connected between the oscillator and amplifier thereby gradually increasing the acoustical output of the reproducer N to that of the normal volume of the organ.

It will be evident that the above described instrument, closely simulates the tone frequency rate of attack and short term drift of large organ pipes while dispensing therewith; that such instrument is small in size and economical to construct and install; and that the maintenance and tuning of the organ is greatly reduced.

It should be understood that the present disclosure is for the purpose of illustration only and that this invention includes all modifications and equivalents which fall within the scope of the appended claims.

I claim:

1. In an electrical musical instrument wherein electronically generated signals are audibly reproduced, a direct power supply, a tunable oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of said oscillator varying as a function of the anode potential, and a circuit interconnecting said anode and said power

supply, said circuit including a reactance having a value whereby as the oscillator is tuned, the time delay required for the anode potential to reach a steady state condition is reflected in the audible output to simulate the initial frequency drift of an organ pipe.

2. In an electrical musical instrument wherein electronically generated signals are audibly reproduced, a direct power supply, a tunable oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of said oscillator varying as a function of the anode potential, and a circuit connecting said anode and said power supply, said circuit including a shunting capacitor having a value whereby as the oscillator is tuned, the time delay required for the potential to reach a steady state condition is reflected in the audible output to simulate the initial frequency drift of an organ pipe.

3. In an electrical musical instrument wherein electronically generated signals are audibly reproduced by means of a loud speaker, a power supply, a tunable oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of the oscillator varying as a function of the anode potential, a circuit interconnecting said anode and said power supply, said circuit having a shunting capacitor so that a time delay is required for the anode potential to reach steady state condition as the oscillator is tuned, and an output network coupling the oscillator to the loud speaker, said network including a filter for shaping the output wave from said oscillator, said filter including a series capacitor, a shunt resistor in series with said series capacitor and a rectifier in parallel with said resistor, the time constant of said filter being short relatively to the frequency of said oscillator whereby the oscillator output is modified to comprise a series of short unidirectional pulses so that the tone of the acoustical output simulates that of a reed stop of an organ.

4. In an electrical musical instrument wherein electronically generated signals are audibly reproduced by means of a loud speaker, a power supply, a tunable oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of the oscillator varying as a function of the anode potential, a circuit interconnecting said anode and said power supply, said circuit having a shunting capacitor so that a time delay is required for the anode potential to reach steady state condition as the oscillator is tuned, and an output network coupling the oscillator to the loud speaker, said network including a filter for shaping the output wave from said oscillator, said filter including a capacitor, a shunting resistor connected in series with said latter capacitor and a shunting capacitor connected in parallel with said resistor, whereby higher frequencies of the oscillator output are attenuated so that the tone of the acous-

tical output simulates that of a flue stop of an organ.

5. In an electrical musical instrument wherein electronically generated signals are audibly reproduced by a loud speaker, a power supply, a tunable oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of the oscillator varying as a function of the anode potential, a circuit interconnecting said anode and said power supply, said circuit having a shunting capacitor so that a time delay is required for the anode potential to reach steady state condition as the oscillator is tuned, and an output network coupling the oscillator to the loud speaker, said network including an amplifier and an articulator as coupling elements, the impedance of said articulator being progressively variable, and means for operating said articulator to vary its impedance whereby the magnitude of the signal supplied to said loud speaker from said oscillator is gradually increased so that the rate of change of the acoustical output simulates that of an organ.

6. An electrical musical instrument comprising an oscillator tuned by key operated switches, a loud speaker for audibly reproducing signals, a power supply, said oscillator including at least one vacuum tube having an anode energized from said supply, the frequency of the output of the oscillator varying as a function of the anode potential, a circuit interconnecting said anode and said power supply, said circuit having a shunting capacitor so that a time delay is required for the anode potential to reach steady state condition as the oscillator is tuned, and an output network coupling the oscillator to the loud speaker, said network including an amplifier and an articulator as coupling elements, said articulator having a plurality of resistors connected in series, a contact movable progressively to shunt said resistors to increase the effective resistance of said network and a pneumatic actuating device for moving said contact whereby the magnitude of the signal supplied to said loud speaker is gradually increased, said device being energized with the closing of any one of said key operated switches so that the rate of increase of the acoustical output simulates that of an organ.

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