June 22, 1954 J. M. HANERT 2,681,585

ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

Filed Nov. 2, 1951 6 Sheets-Sheet 1

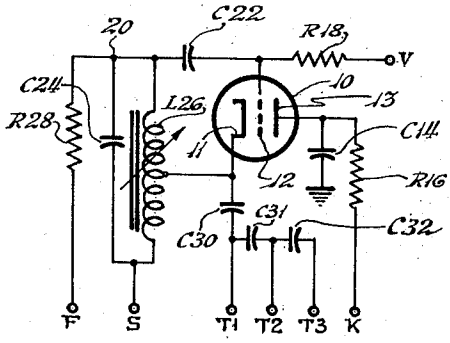


Fig. 1.

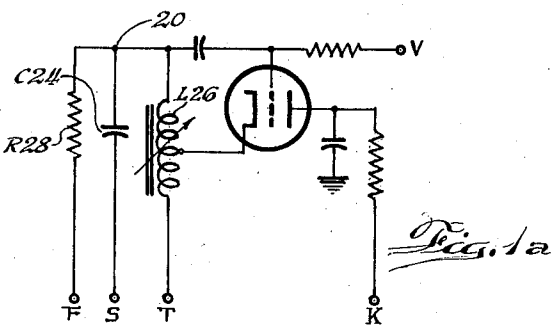


Fig. 1a

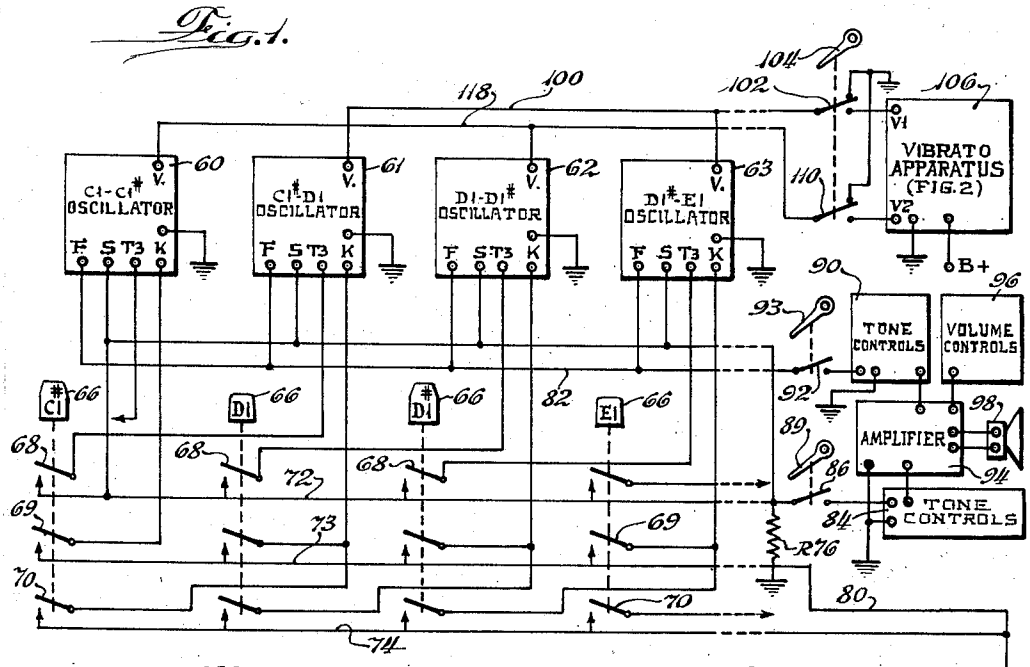


Fig. 3.

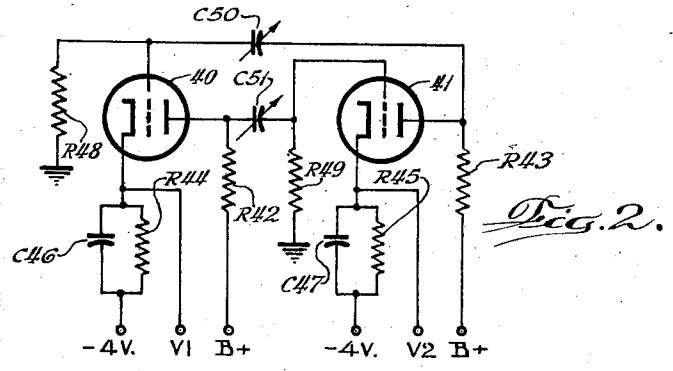


Fig. 2.

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ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

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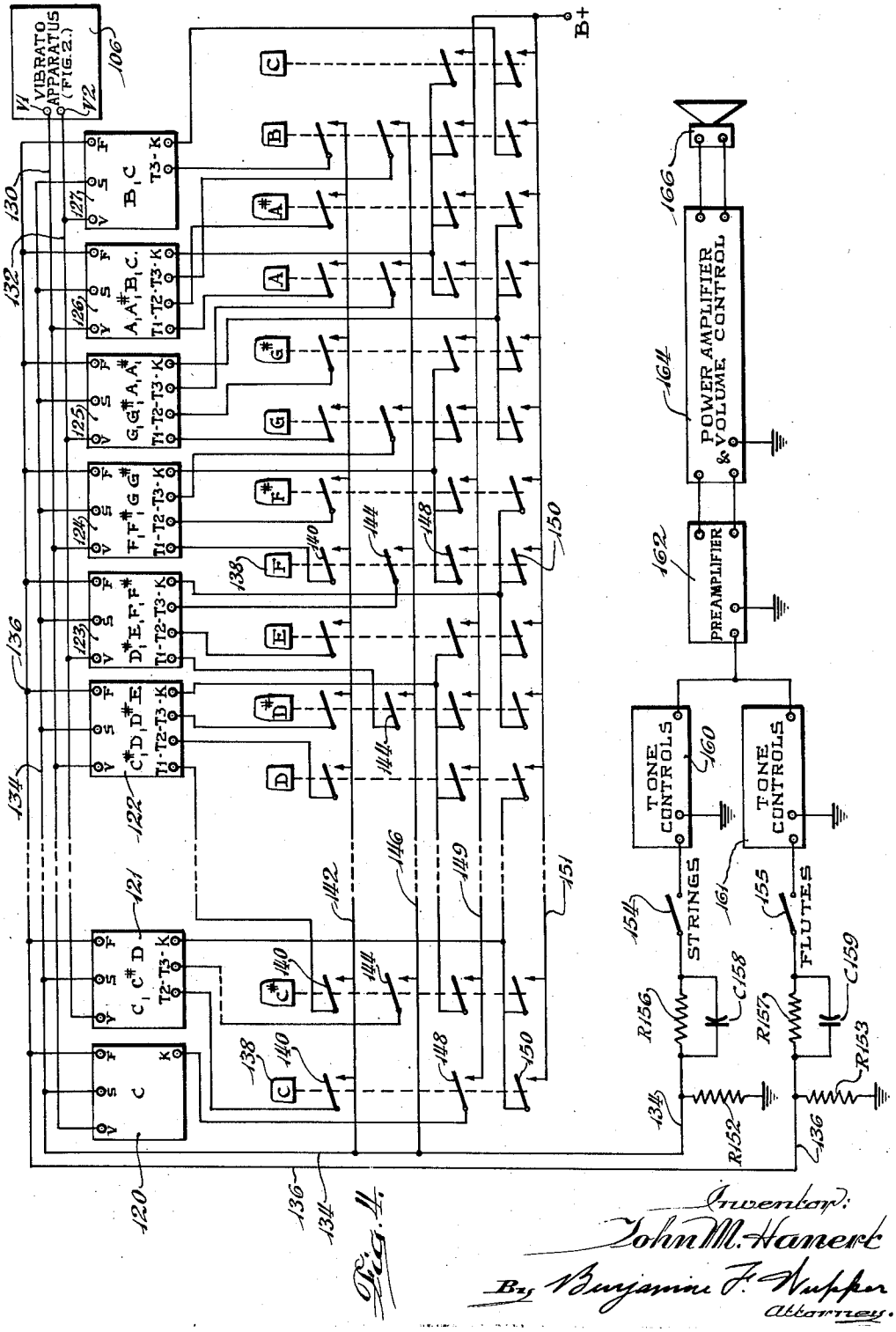


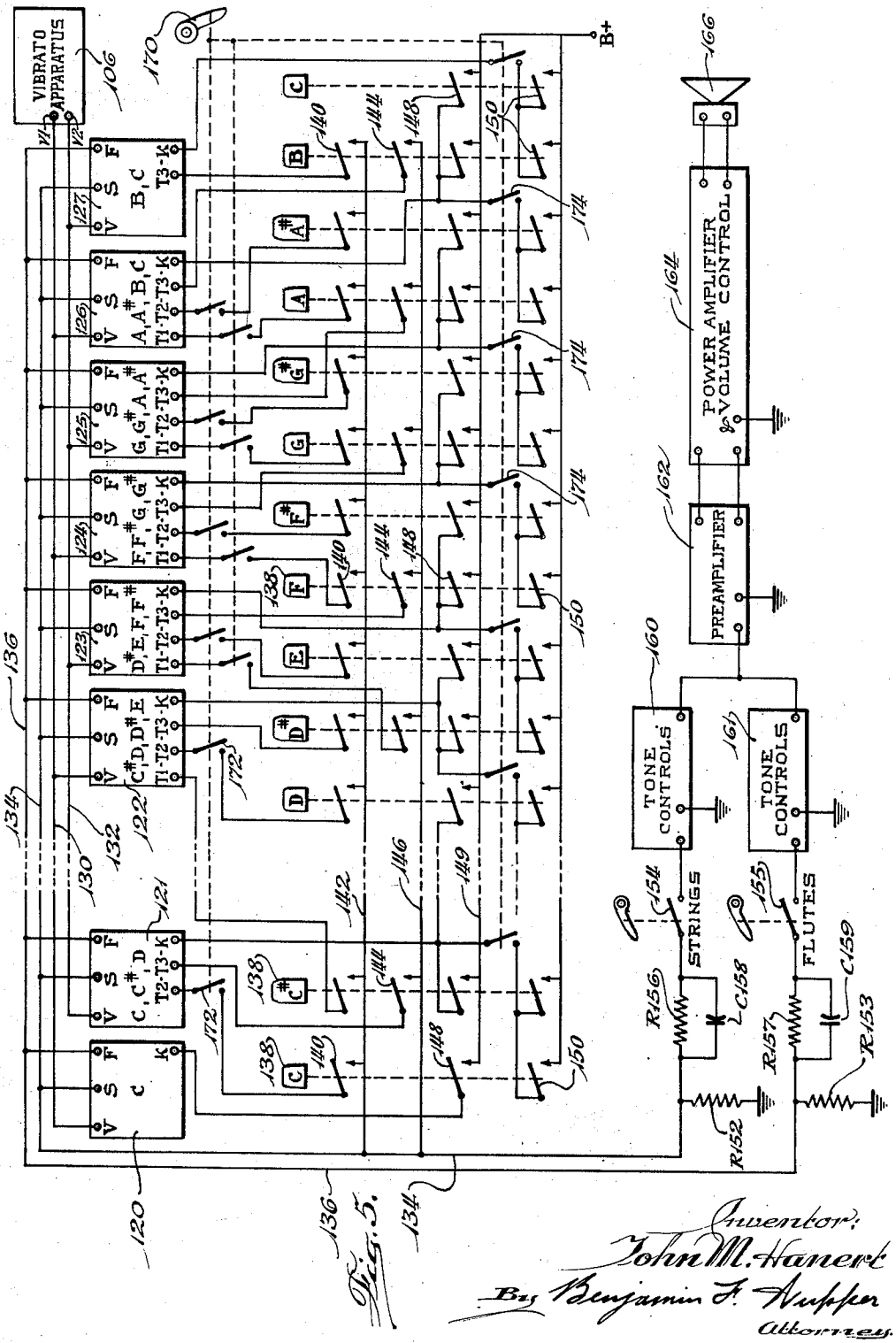
Fig. 1.

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ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

Filed Nov. 2, 1951 6 Sheets-Sheet 3



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June 22, 1954 J. M. HANERT 2,681,585

ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

Filed Nov. 2, 1951 6 Sheets-Sheet 4

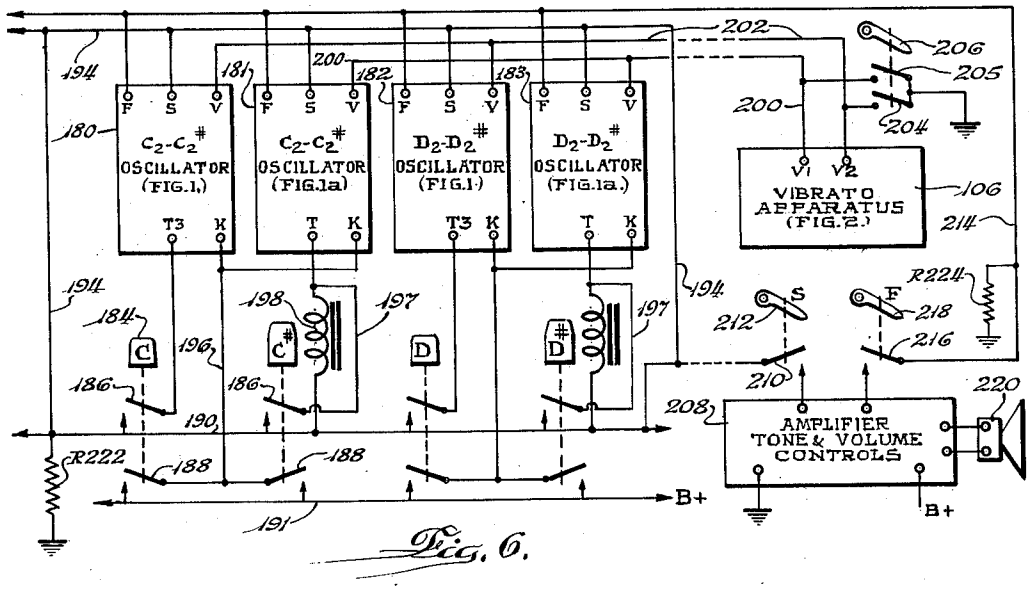


Fig. 6.

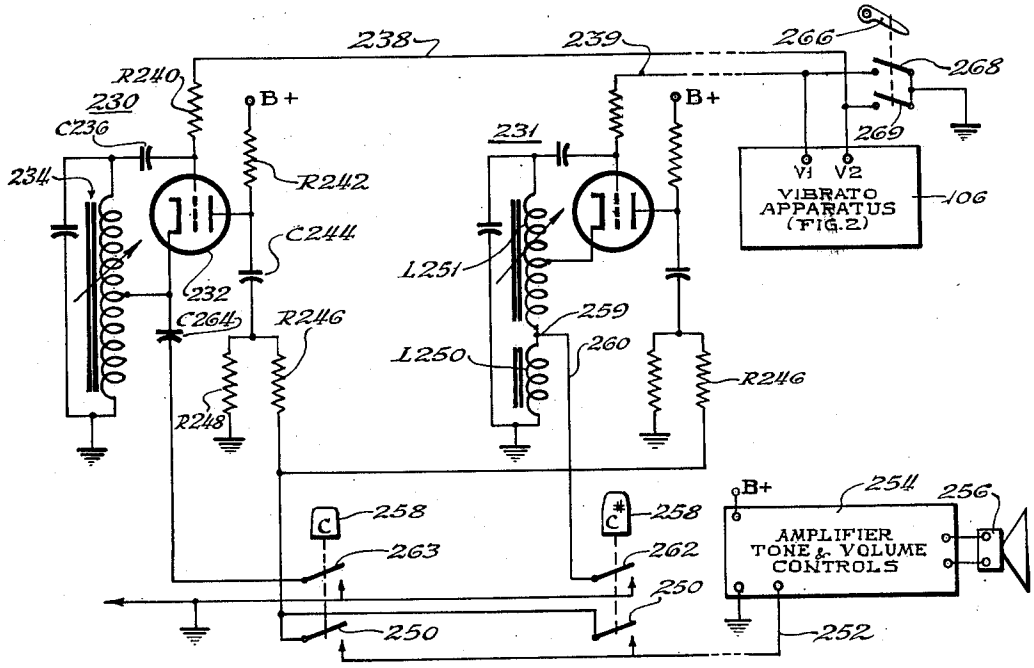


Fig. 7.

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ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

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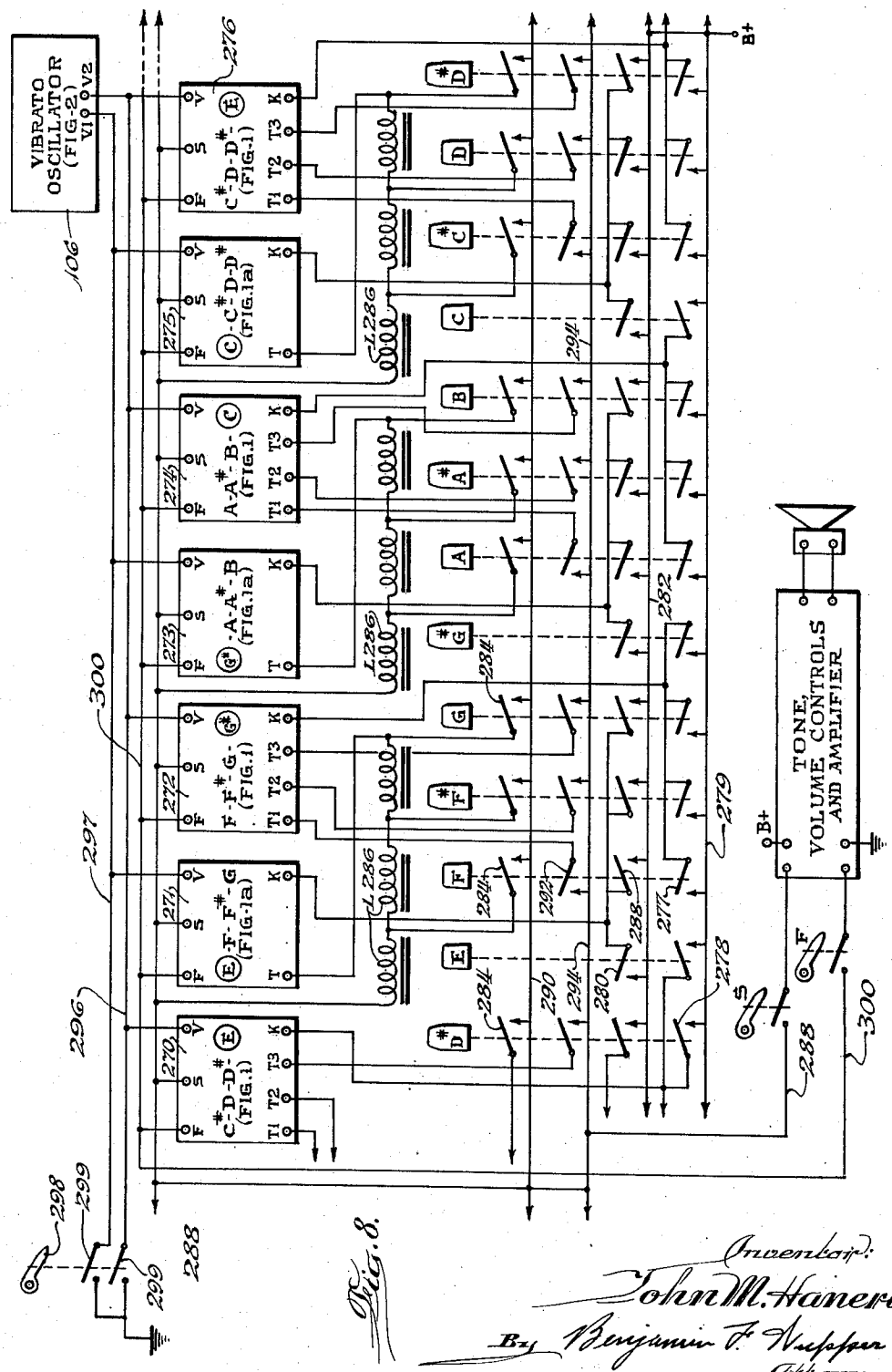


Fig. 8.

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ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

Filed Nov. 2, 1951 6 Sheets-Sheet 6

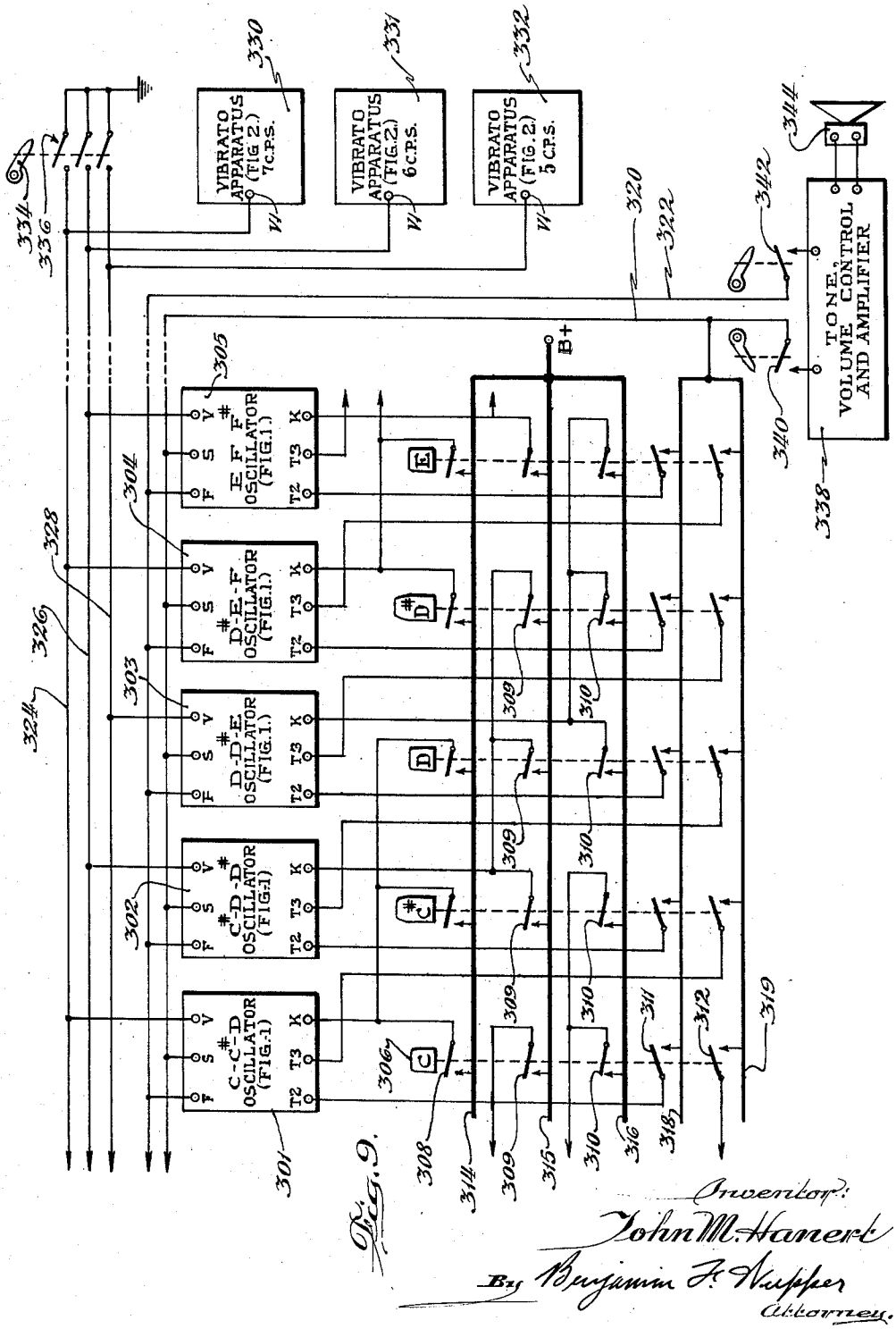


Fig. 9.

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Patented June 22, 1954 2,681,585

UNITED STATES PATENT OFFICE

2,681,585

ELECTRICAL MUSICAL INSTRUMENT PRODUCING CHORUS EFFECTS

John M. Hanert, Des Plaines, Ill., assignor to Hammond Organ Company, a corporation of Delaware

Application November 2, 1951, Serial No. 254,574

24 Claims. (Cl. 84—1.24)

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My invention relates generally to electronic musical instruments and more particularly to instruments of the organ type in which improved chorus effects may readily be obtained.

It is the primary object of the invention to produce a polyphonic electronic musical instrument of the organ type in which the tones are generated by electronic oscillators, in which each oscillator serves to supply tone frequency signals for two or more keys and in which at least four oscillators are provided for an octave of keys all of which have overlapping tuning ranges to produce a desirable chorus effect when simultaneously sounded upon the depression of a single playing key.

A further object is to provide an electronic organ in which a plurality of signals of nearly the same fundamental frequency are transmitted to the output system and are sounded upon the depression of a single key to produce a rich chorus of tones.

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

Figure 1 is a schematic wiring diagram of an oscillator which may be tuned to any one of three adjacent semitones lower than its normal frequency by adding capacitors in series in its tuning circuit;

Figure 1*a* is a similar diagram of an oscillator which may be tuned to operate at higher frequencies by adding inductive tuning elements to its tuning circuit;

Figure 2 is a schematic wiring diagram of a multivibrator utilized to produce signals of vibrato frequency (5 to 7 C. P. S.) for frequency modulating the electronic oscillators used in the instrument;

Figure 3 is a block and schematic wiring diagram of an electronic organ utilizing oscillators of the type shown in Fig. 1 and in which two oscillators are energized and supply signals to the output system upon depression of a single key;

Figure 4 is a schematic wiring and block diagram of a second form of the invention in which oscillators of the type of Fig. 1 are utilized, each oscillator supplying any one of four adjacent semitone signals, and in which depression of a single key results in the transmission to the output system of two tone signals of substantially the same fundamental frequency;

Figure 5 is a schematic wiring and block diagram of a third form of the invention which is similar to that illustrated in Fig. 4 but has selectively operable means for obtaining the chorus effect;

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Figure 6 is a schematic wiring and block diagram of a fourth form of the invention in which the oscillators of Fig. 1 and Fig. 1*a* are used in alternation to produce a chorus effect.

Figure 7 is a wiring and block diagram of a fifth form of the invention in which the oscillators operate continuously, but is otherwise similar to that shown in Fig. 6;

Figure 8 is a schematic wiring and block diagram of a sixth form of the invention in which the oscillators of Fig. 1 and Fig. 1*a* are used in alternation; and

Figure 9 is a schematic wiring and block diagram of an instrument employing the oscillators of the type of Fig. 1, using each oscillator for three adjacent semitones in overlapping relation.

Referring to Fig. 1*a* the oscillator comprises a triode 10 consisting of a cathode 11, control grid 12, and plate 13. The plate is connected to ground through an attack and decay capacitor C14 and is adapted to be connected to a source of plate current through a resistor R16 which is connected between the plate and a terminal K. As will appear hereinafter the terminal K is connected to one or more key operated switches which in turn connects the plate to a source of plate current.

The grid 12 is connected to a terminal V through a decoupling resistor R18. The terminal V may be connected to terminal V1 or terminal V2 of the vibrato frequency generator shown in Fig. 2 and hereinafter to be described. The grid 12 is also connected to a terminal 20 of a resonant mesh through a capacitor C22, the resonant mesh comprising a capacitor C24 and a variable tuning inductance L26 connected in parallel between the terminal 20 and an output signal terminal S. The terminal 20 is also connected through a decoupling resistor R28 to a signal output terminal F. A tap on the inductance L26 is connected to the cathode 11 and is connected through a capacitor C30 to a terminal T1. A capacitor C31 is connected between terminals T1 and T2 and a capacitor C32 is connected between terminals T2 and a terminal T3.

This oscillator is described in greater detail in my copending application Serial No. 224,276, filed May 3, 1951, now abandoned, and certain features thereof are disclosed in my prior application Serial No. 169,891, filed June 23, 1950, now Patent No. 2,645,968 issued July 21, 1953. Other

features incorporated therein are disclosed and claimed in the copending applications of Laurens Hammond Serial No. 96,107, filed May 28, 1949 and Serial No. 180,289, filed August 18, 1950.

For the purposes of this application it will be sufficient to note that when the terminal K is connected to a source of plate current the oscillator will commence operating at gradually increasing amplitude depending upon the time constant of R16 and C14, and that the frequency at which it normally oscillates will be determined mainly by the inductance L26 and capacitor C24 whenever terminals T1, T2, and T3 are not connected to any potential source. Further, it will be understood that the capacitor C30 is of such value that when terminal T1 is connected to terminal S the oscillator will oscillate at a frequency three semitones lower than its normal frequency. When the terminals T2 and S are connected, capacitors C30 and C31 will be effective in the resonant circuit and the value C31 is so chosen that the oscillator will then oscillate at a frequency two semitones below its normal frequency. When the terminals T3 and S are connected so that the three capacitors C30, C31, and C32 in series are effectively in the resonant tuning circuit, the oscillator will oscillate at a frequency one semitone below its normal frequency.

With the terminal V connected to a suitable source of vibrato signals the oscillator frequency will shift through a range of about 3 per cent of its normal frequency at the rate of the vibrato signal frequency, usually 5 to 7 cycles per second.

The oscillator of Fig. 1*a* is similar to that shown in Fig. 1 and the corresponding references have been applied to the corresponding parts and a description thereof will not be repeated. It will be noted that in Fig. 1*a* the terminal S is connected to the capacitor C24 but is not connected to the inductance L26, the latter being connected between the terminal 20 and a terminal T. As will appear hereinafter the oscillator will operate at its normal frequency when the terminals S and T are connected and that it will oscillate at decreased frequencies when one or more separate inductance elements are connected in series between the terminals S and T. In this respect the oscillator is similar to that more fully described and claimed in my copending application Serial No. 51,409, filed September 27, 1948.

The signals appearing at the F terminals of these oscillators will be substantially sine wave character, that is, of flute-like tone quality, while the signals appearing at the S terminals will contain many harmonics and will thus be of string tone quality.

In Fig. 2 there is illustrated a relaxation oscillator comprising triodes 40 and 41, supplied with plate current through load resistors R42 and R43 respectively. The cathodes of these triodes are connected to a −4 volt potential source through self-biasing resistors R44 and R45, these resistors having by-pass capacitors C46, C47 in parallel therewith. The cathode of the triode 40 is connected to an output terminal V1 while the cathode of triode 41 is connected to an output terminal V2. The grid of triode 40 is connected to ground through a grid return resistor R48 while the grid of triode 41 is connected to ground through a resistor R49. The plate of triode 41 is connected to the grid of triode 40 through a variable feedback capacitor C50 while the plate of triode 40 is similarly connected to the grid of triode 41 through a variable capacitor C51.

Upon applying the operating voltages the oscillator will operate at a frequency determined mainly by the values of R40, R49, C50, and C51 and these capacitors may readily be adjusted to cause oscillation at a vibrato frequency of 5 to 7 cycles per second. It will be noted that the signals appearing at the terminals V1 and V2 will be of opposite phase, that is, as the potential on one terminal increases the potential on the other terminal decreases.

The instrument shown in Fig. 3 utilizes oscillators of the type shown in Fig. 1, four oscillators 60, 61, 62, and 63 being illustrated as representative of the 60 or more oscillators which may be employed in a complete instrument. It will be noted that these four oscillators do not utilize the terminals T1 and T2, only the terminal T3 being used to lower the oscillator frequency by one semitone. The oscillator 60 is tuned to generate the frequency C1 and C1#; the oscillator 61, C1# and D1; the oscillator 62, frequencies D1 and D1#; and oscillator 63, D1# and E1, it being noted that there are thus two sources of tone signals for each note of the scale. The tuning of the two sources which supply signals of the same nominal pitch is not exact. For example the nominal C1# frequencies generated by the oscillators 60 and 61 may be from 0.25 per cent to 1.7 per cent sharp and flat, respectively, relative to the exact pitch of the note C1#. Thus the average of the two signals of the same nominal pitch supplied by two oscillators will be of exactly the correct pitch.

Four representative keys 66 for the notes C1#, D1, D1#, and E1 are illustrated, each key operating three switches 68, 69, and 70. One pole of each of the switches 68 is connected to a bus bar 72; one pole of each of the switches 69 is connected to a bus bar 73; and one pole of each of the switches 70 is connected to a bus bar 74. Bus bar 72 is connected to the S terminals of all of the oscillators and is connected to ground through a coupling resistor R76. The bus bars 73 and 74 are connected to the B+ terminal. When a key 66 is depressed its switch 68 closes before either of the switches 69 or 70 is closed, and upon release of the key, switches 69 and 70 open prior to the opening of switch 68. This sequence of switch operation prevents transmission to the output system of undesirable transients produced incidental to tuning the oscillators.

The F terminals of all of the oscillators are connected to a collector conductor 82 while, as previously indicated, all the S terminals are connected to the bus bar 72. The bus bar 72 is adapted to be connected to suitable tone control devices 84 upon closure of a switch 86 operable by a tablet 89, while similarly the collector conductor 82 may be connected to tone controls 90 upon closure of a switch 92 operable by a control tablet 93. The signals as modified by the tone controls 84 and 90 are supplied to an amplifier 94 which is provided with suitable volume controls 96 and the output of which is transmitted to a speaker 98.

Alternate oscillators such as 61 and 63 have their V terminals connected to a conductor 100 which upon operation of a switch 102 by a suitable tablet 104 may be connected to the V1 terminal of a suitable vibrato apparatus 106, which may be of the type shown in Fig. 2. Intermedi-

ate oscillators such as 60 and 62 have their V terminals connected to a conductor 108 which upon closure of the switch 110 by operation of the tablet 104 may be connected to the V2 terminal of the vibrato apparatus 106. When the tablet 104 is not operated (in the position which is shown in Fig. 3) the switches 102 and 110 connect conductors 100 and 108 to ground.

The instrument may be cased in the customary organ console provided with bass note pedals, one or more expression pedals, and various tone quality control stop tablets, in addition to those shown in Fig. 3. The instrument is played in the usual manner of an organ but it will be noted that depression of any of the keys will connect the T3 terminal of the next adjacent higher oscillator to the conductor 72 and thus, referring to Fig. 1, connect the capacitors C30, C31, and C32 in series between the cathode and terminal S. It will be recalled that these capacitors are of such value that the oscillator will be detuned by a semitone. After the switch 68 of an operated key is closed the switches 69 and 70 will be closed thereby connecting the K terminals of the two oscillators to the source of plate current, the B+ terminal, and these two oscillators will commence oscillating, impressing flute-like tone signals upon the collector conductor 82 and string-like tone signals on the bus bar 72.

These signals, as desired, are transmitted to the output system of the instrument, being ultimately translated into sound by the speaker 98. As previously indicated, because the oscillators providing tone signals of the same nominal pitch are tuned to provide signals respectively slightly sharp and flat relative to the nominal pitch, the tonal output of the instrument is exceedingly rich giving the impression that a large group of instruments is being heard. Even though the oscillators are initially tuned exactly to the same pitch, random changes in their frequencies relative to one another will occur in the course of time due to aging of the various components, or due to variations in temperature, humidity, and possibly due to other factors.

This desirable impression of a chorus of instruments is further enhanced by virtue of the use of vibrato modulation of opposite phase upon the two oscillators supplying signals of the same nominal pitch. This feature of utilizing vibrato signals of opposite phase in various types of musical instruments is more fully disclosed and claimed in my copending application, Serial No. 223,376, filed April 27, 1951. Even though the vibrato apparatus is not used, a highly desirable chorus effect will be obtained because of the natural or introduced slight differences in the frequencies generated by the several oscillators of the same nominal pitch.

In the instrument shown in Fig. 4, oscillators of the type shown in Fig. 1 are employed. For purpose of illustration, eight oscillators 120 to 127 are shown. The oscillator 120 would be the same as the oscillator shown in Fig. 1, except that the tuning terminals and tuning capacitors C30, C31, and C32 would not be required. Similarly, the oscillator 121 would not have to have a tuning terminal T1 and the oscillator 127 need not have tuning terminals T1 and T2. Additional oscillators, similar to the oscillators 122 to 126, could be connected in the circuit in the same manner as these oscillators, as indicated by the broken circuit lines.

Each of the terminals V of alternate oscillators are connected to the V1 terminal of the vibrato apparatus 106 by a conductor 130, while alternate intermediate oscillators have their terminals V connected to the V2 terminal of the vibrato apparatus by a conductor 132. The S terminals of all of the oscillators are connected to a conductor 134, while the F terminals of all of the oscillators are connected to a conductor 136. Disregarding the two oscillators 120 and 121 at the lower end of the scale, and the single oscillator 27 at the upper end of the scale, it will be noted that each oscillator is capable of supplying four frequencies, and since signals of the same nominal frequency are provided upon depression of any key, it will be apparent that the number of oscillators required will be one-half the number of tones in the gamut of the instrument, or more particularly, six oscillators will be required for each octave of the instrument, plus two additional oscillators, due to the fact that the end oscillators 120, 121, and 127 are not used in a fully efficient manner.

Each of the keys 138 operates three or four switches. Each key operates a switch 140 for tuning one of the oscillators, these switches being connected to a bus bar 142 which is connected to the conductor 134. Some of the keys, such as C#, D#, and F, operate additional tuning switches 144 which connect the tuning terminal on another oscillator to a bus bar 146, which is also connected to the conductor 134. Each of the keys also operates two additional switches 148 and 150, which co-operate respectively with bus bars 149 and 151, both of these bus bars being connected to a B+ terminal.

The conductors 134 and 136 are respectively connected to ground through signal resistors R152 and R153. The conductor 134 is connected to switch 154 through a decoupling resistor R156 having a capacitor C158 in parallel therewith. Similarly, the conductor 136 is connected to a switch 155 through a resistor R157 having a capacitor C159 in parallel therewith. The other poles of the switches 154 and 155 are connected respectively to tone controls 160 and 161, which may be of any well-known type comprising various selectively usable filtering meshes. The outputs of both tone controls are coupled to a preamplifier 162 which feeds the signals to a power amplifier and volume control 164, and the output of the latter is supplied to one or more speakers 166.

It will be noted that when any key (except the C and C# key in the lowest octave and highest C key) is depressed, two adjacent oscillators, for example oscillators 123 and 124, are tuned to the same nominal frequency. If the F key 138 is depressed, closure of its switch 140 will tune the oscillator 124 to a pitch three semitones below its nominal G# pitch, and by closure of its switch 144, will tune the oscillator 123 one semitone below its nominal F# pitch. After the oscillators have had their tuning circuits rendered effective by closure of the switches 140 and 144, switches 148 and 150 are closed to connect the K terminals of oscillators 124 and 123, to the B+ bus bars 149 and 151, respectively.

The tuning of the oscillators need not be of a high degree of precision. In fact, if the oscillators are very slightly out of tune, the chorus effect is enhanced.

The vibrato apparatus 106 may be provided with a means for rendering it ineffective in the same manner as shown in Fig. 3. When the

vibrato apparatus is connected to the oscillators, as it usually will be in normal use of the instrument, the two adjacent oscillators, such as 123 and 124, will have out of phase vibratos so that a rich chorus effect will be obtained, as more fully described in my aforesaid application, Serial No. 223,376. Depending upon the tone quality required, either switch 154 or switch 155, or both, are closed and the tone controls 160 and 161 adjusted. The instrument is then played in the usual manner.

From the foregoing, it will be apparent that the instrument shown in Fig. 4, although it requires substantially one-half as many oscillators as keys, is nearly the equivalent of an instrument having two oscillators per key, with the exception that some adjacent tones and semitones which are called for infrequently in music, will not in all cases sound in chorus but will nevertheless sound with the correct pitches. Due to the inherent dissonance produced when playing these intervals, the lack of chorus on these particular intervals is not seriously objectionable, in fact, it may be hardly noticeable. Where low cost of production is a primary consideration, the above noted minor inadequacies may be overlooked.

The instrument shown in Fig. 5 is quite similar to that shown in Fig. 4, and the same reference characters have therefore been applied to the corresponding parts in the two figures, and a detailed description of such parts will not be repeated.

The instrument of Fig. 5 differs from that in Fig. 4 in that the chorus effect may be used or not, at the will of the player. The control for the chorus effect comprises a tablet 170 which operates a plurality of switches 172 connected to some of the tuning terminals of the oscillators, and a plurality of switches 174 connected to most of the keying terminals K of the oscillators. These switches are arranged in the tuning circuit such that when a key, for example the F key 138, is depressed, closure of its switch 140 has no effect. Closure of its switch 144 tunes oscillator 123 to the frequency of the note F, and subsequent closure of its switch 148 is effective to supply plate current to the oscillator 123. Closure of its switch 150 has no effect, since the circuit between this switch and the K terminal of oscillator 124 is broken by the opening of one of the switches 174. Thus only the oscillator 123 is rendered effective to supply the signal of the pitch of the note F to the output system. When the chorus control tablet 170 is operated to close the switches 172 and 174, the instrument will be effectively the same as that shown in Fig. 4, and will operate in the same manner to produce a rich chorus effect.

In the form of the invention shown in Fig. 6, there is one oscillator per key, but each oscillator is capable of providing two frequencies. Four oscillators 180, 181, 182, and 183 are illustrated as representative of the complete signal generating system of the instrument. Alternate oscillators, such as 180 and 182, are of the type shown in Fig. 1, while the intermediate oscillators, such as 181 and 183, are of the type shown in Fig. 1*a*. Each of the keys 184 operates a pair of switches 186 and 188, the switch 186 being closed prior to the closure of switch 188 upon depression of the key, and opened after switch 188 upon release of the key. The switch 186 for alternate keys, such, for example, as the keys C and D, connect the T3 terminals of their oscillators to a bus bar 190 which is connected by a conductor 194 with the S terminals of all of the oscillators. One pole of the switch 188 for the C key is connected by branched conductor 196 to the K terminals of both oscillators 180 and 181. The other poles of switches 188 are connected to a plate current supply bus bar 191.

Depression of an intermediate key, such as the C# key, by closing its switch 186, shunts a conductor 197 around an inductance L198, thus connecting the T terminal of oscillator 181 to the bus bar 190, and thereby effectively changing the tuning of the oscillator 181, so that it will oscillate at C# pitch. The inductance L198 is normally in the tuning circuit of the oscillator, being connected between its T and S terminals, and is of such value that the pitch of the oscillator is lowered by one semitone when it is effectively connected in the tuning circuit. Closure of the switch 188 associated with the C# key will cause plate current to be supplied to the K terminals through bus bar 191 and branched conductor 196.

Alternate oscillators, such as oscillators 180 and 182, have their V terminals connected to a conductor 200 leading to the V1 terminal of the vibrato apparatus 106, while the intermediate oscillators such as 181 and 183, have their V terminals connected by a conductor 202 to the V2 terminal of the vibrato apparatus.

When the vibrato effect is not desired, conductors 200 and 202 are connected to ground by switches 204 and 205 operable by a chorus control tablet 206.

The conductor 194, which is connected to the S terminals of all of the oscillators, may be connected to an amplifier 208, which may include tone and volume controls this being effected by closure of a switch 210, operable by a tablet 212.

The F terminals of all of the oscillators are connected to a conductor 214 which may be connected to the amplifier 208 by closure of a switch 216 operated by a tablet 218. A speaker 220 is connected to the outlet of the amplifier 208. The conductors 194 and 214 are connected to ground through signal resistors R222 and 214, respectively. As in the instruments shown in Figs. 4 and 5, suitable means may be employed to decouple these two output circuits, these being considered as included within the block 208 representing the amplifier, tone, and volume controls.

Upon depression of a key, such as the C key 184, its associated oscillator, such as 180, will be tuned one semitone below its normal C# frequency, and thus provide a signal of C pitch. Closure of its switch 188 will result in supplying plate current to both oscillators 180 and 181 by connecting their K terminals to the B+ bus bar 189. The oscillator 181 will oscillate at its normal C pitch.

When a key associated with an intermediate oscillator, such as the key C# associated with the oscillator 181, is depressed, closure of its switch 186 results in connecting an inductance L198 between its T terminal and the bus bar 190. The inductance L198 has a value such as to raise the pitch at which the oscillator 181 oscillates one semitone above its normal frequency, and this oscillator will therefore generate a signal of C# pitch. Closure of the switch 188 associated with this C# key, will result in connecting the K terminals of both oscillators 180 and 181 to the B+ bus bar 191. Thus both of the oscillators will oscillate at this C# pitch.

Because the vibrato control switches 204 and 205 will normally be open, the vibrato frequency

modulation of each pair of adjacent oscillators will be in opposite phase, with the result that a rich chorus effect will be obtained. Although in this instrument of Fig. 6 there are as many oscillators as keys, the effect produced is substantially the same as if there were two oscillators per key.

In this particular instrument the even numbered oscillators may use a single capacitor of the same value as the series of capacitors C30, C31, and C32 of Fig. 1 in place of these three capacitors.

Instead of using the normally non-oscillating type of oscillators as employed in the instrument shown in Fig. 6, continuously operating oscillators 230 and 231 of the type shown in Fig. 7 may be employed. These oscillators are similar to the oscillator shown in Fig. 1*a* and are illustrative of the thirty or forty-four pairs of oscillators which may be employed in a complete instrument.

Each oscillator comprises a triode 232 having an inductance-capacitance tuning mesh 234 connected between the grid of the triode and ground through a capacitor C236, the grid being likewise connected to one of two conductors 238, 239, through a grid resistor R240. The plate of the triode is connected to a B+ terminal by a load resistor R242, and the signal is derived from the plate through a capacitor C244 which is in series with a decoupling resistor R246, the capacitor also being connected to ground through a resistor R248. The resistors R246 of the pair of oscillators are connected to one pole of each of a pair of switches 250. The other poles of these switches are connected by a conductor 252 to an amplifier 254 which may include tone and volume controls, and the output of which is supplied to a speaker 256. The switches 250 are shown as being operable by keys 258 for the notes C and C#.

It will be noted that the tuning mesh for the oscillator 231 has an additional inductance L259 connected in series with its main tuning inductance L251 by a conductor 259 connected by conductor 260 to a switch 262 operated by the C# key 258. The value of inductance L250 is so chosen that when it is connected to ground by closure of the switch 262, the oscillator 231 will operate at a frequency one semitone higher than its normal frequency.

A switch 263 operable by the C key, has one pole connected to the cathode of triode 232 through a capacitor C264. The cathode is also connected to a tap on the tuning inductance, this tap being so positioned, and the value of the capacitor C264 being such, that when the switch 263 is closed, the oscillator 230 will operate at a pitch one semitone lower than its normal frequency of oscillation. This oscillator normally operates at the pitch C#, whereas the oscillator 231 normally operates at the pitch C.

As in the instrument shown in Fig. 6, there is provided a vibrato control tablet 266 for operating switches 268 and 269 to connect the conductors 238 and 239 respectively to ground whenever the vibrato effect is not desired.

The instrument of Fig. 7 operates in essentially the same manner as that shown in Fig. 6, except that the oscillators operate continuously. It is therefore essential that the tuning switches 262, 263 be closed prior to the closing of the switches 250 on the depression of the keys, and that they open after the switches 250 upon release of the keys, thereby to avoid the sounding of undesirable transients which may be present as the pitch of the oscillator is changed.

Further to illustrate the breadth of the underlying principles of the invention, an instrument is illustrated in Fig. 8, which in general is similar to that shown in Fig. 5, but differs in the manner in which one-half of the oscillators are tuned. Seven oscillators 270 to 276 are illustrated as representative of the generating system of the complete instrument, it being understood that there are half as many oscillators as there are semitones in the gamut of the instrument. Alternate oscillators are preferably of the type shown in Fig. 1, while the intermediate oscillators are of the type shown in Fig. 1*a*.

Each key operates two switches 277 and 278 to connect the K terminals of two associated oscillators to bus bars 279 and 282, the latter being connected to the B+ terminal. Three out of each group of four keys also operate switches 284. The lowermost of each group of switches 284, upon closure, connects two of a series of three inductance elements L286 between the T and S terminals of its associated oscillator. For example, the oscillator 271 is normally tuned to oscillate at the pitch of the note E. It operates at this pitch when all three of the inductances L286 are connected between its T terminal and a conductor 288, the latter being connected to the S terminals of all oscillators. It is therefore not necessary to provide a switch 284 for the key E. However, when switch 284 for the key F is operated, the leftmost of the three inductances L286 in series will have its terminals connected together, because the switch 284 has its other pole connected to a bus bar 290, which in turn is connected to conductor 288. Similarly, when the F# key is depressed, the two leftmost inductances L286 will be short-circuited and thus rendered ineffective in the tuning circuit of the oscillator 271. When the switch 284 for the key G is closed, all three inductances will be shunted out of the tuning circuit of the oscillator 271.

The values of the inductances L286 differ slightly from one another, but are of such values that as each additional inductance is effective in the tuning circuit, the pitch at which the oscillator operates will be reduced by successive semitone intervals. Three of each group of four keys operate switches 292, which have one pole connected to a T1, T2, or T3 terminal of the even numbered oscillators, such as the oscillator 272, the other poles of these switches being connected to a bus bar 294 which is connected to the conductor 288.

The connections are such that when a key, such as the F key, is depressed, two of the oscillators will be tuned to the same nominal pitch, and because, as in the previous instruments, the two oscillators are frequency modulated by vibrato signals of opposite phase, an increased chorus effect will be obtained.

It will be noted that alternate oscillators 270—276 are connected to the V2 terminal of the vibrato oscillator apparatus 106 by a conductor 296, while the V terminals of the intermediate oscillators are connected by a conductor 297 with the V1 terminal. These last named conductors may be connected to ground by operation of a vibrato control tablet 298 which operates a pair of switches 299.

When, for example, the F key is depressed, the oscillator 271 is tuned to the pitch of the note F by virtue of the fact that two induct-

ances L286 are connected in the tuning circuit when the switch 284 is closed. Closure of the switch 292 tunes the oscillator 272 to the frequency F by virtue of the fact that this switch is connected to terminal T1 of the oscillator. These two oscillators are thereafter supplied with plate current by closure of switches 288 and 277.

Every fourth key does not operate a switch 284 or 290, since two adjacent oscillators are normally tuned to oscillate at the frequency represented by such key as indicated by the encircled letters on the blocks representing these oscillators.

The terminals S of all of the oscillators are connected to the conductor 288 while their terminals F are connected to a conductor 300, these conductors being connected to the output system of the instrument in the same manner as described with reference to the form of the invention shown in Fig. 5.

The embodiment of the invention shown in Fig. 9 differs from those previously described in that it has one oscillator of the type shown in Fig. 1 for each semitone within the gamut of the instrument, each oscillator being tunable to any of three adjacent semitone frequencies, and in that depression of any single key causes the sounding of three signals of the same nominal pitch frequency modulated at different vibrato rates.

Five oscillators 301 to 305 are shown as representative of the generating system of the complete instrument, it being understood that there is one oscillator for each semitone interval plus two oscillators for the two highest (or lowest, or both highest and lowest) pair of semitones within the gamut of the instrument.

Each of the keys 306 operates five switches 308 to 312. The switches 308 to 310 are respectively co-operable with bus bars 314, 315, and 316, which are connected to a suitable source of plate current indicated as a B+ terminal. The switches 311 and 312 co-operate respectively with bus bars 318 and 319, which are connected to a conductor 320, the latter being connected to the S terminals of all of the oscillators. The switches 308 for three adjacent playing keys 306, are connected together. For example, the switches 308 for the keys C, C♯, and D are connected to the terminal K of oscillator 301. In a similar manner, the switches 309 associated with the three adjacent semitone playing keys, are connected to the K terminal of the oscillator 302, and the switches 310 for the keys D, D♯, and E are connected to the K terminal of oscillator 303.

The switches 311 are connected to T2 terminals of the oscillators whose lowest frequency is the same as that of the key which operates the switch. For example, the switch 311, operated by key C, is connected to the oscillator 301, which generates the frequencies C, C♯, and D.

The switches 312 of each key are connected to the T3 terminal of the oscillator, which generates a middle frequency of the same pitch as the key which operates the switch. Thus, for example, the switch 312, operated by the C♯ key, is connected to the T3 terminal of the oscillator 301, which generates a middle frequency of C♯.

The F terminals of all of the oscillators are connected to a conductor 322. Every third generator, such as the generators 301 and 304, have their V terminals connected to a conductor 324. The respectively adjacent oscillators, such as 302 and 305, have their V terminals connected to a conductor 326, and the remaining oscillators, such as oscillator 303, have their V terminals connected to a conductor 328.

The conductors 324, 326, and 328, are connected respectively to three vibrato apparatuses 330, 331, and 332, similar to that shown in Fig. 2, but which are adjusted to generate vibrato pulses at different frequencies, such, for example, as 5, 6, and 7 C. P. S. A vibrato control tablet 334 operates a three pole switch 336 by which the conductors 324, 326, and 328 may be connected to ground when the chorus effect is not desired. The conductor 320 may be connected to tone and volume controls and amplifier 338, upon closure of tablet operated switch 340, while the conductor 322 may be similarly connected to the output system by tablet operated switch 342. The output system includes one or more speakers 344.

This modified form of the invention is played in the usual manner of an organ, and the tones produced will have an extremely rich full organ chorus effect because of the different vibrato rates by which the oscillators are frequency modulated. Upon depression of a single key, three tone signals of the same nominal pitch will be supplied to the output system. The tonal result will be equivalent to that of a large chorus of instruments, because the vibrato rates will not be perceptible to a noticeable extent, and no prominent beat effects will be heard.

The modulation of the oscillators in the previously described forms of invention may be accomplished by using two vibrato oscillators of different frequencies instead of using out of phase pulses from a single vibrato oscillator, although the latter method of frequency modulation is preferred for instruments in which but two signals are supplied to the output system upon the depression of a single key.

In each form of the invention disclosed herein an oscillator is utilized which can be tuned to any one of several frequencies, preferably not more than four different frequencies, and upon depression of any key, signals from at least two different oscillators are supplied to the output system. Since the oscillators are intentionally tuned to pitches slightly sharp or slightly flat with respect to the nominal pitch, or in the course of time become slightly out of tune, a chorus effect is obtained.

In some forms of the invention one oscillator is required for each note within the gamut of the instrument, but in others the oscillators may be tuned to any of three or four pitches, thus substantially reducing the number of oscillators required for a complete instrument capable of producing the chorus effect by having more than one oscillator sound at approximately the nominal pitch whenever a single playing key corresponding to that pitch is operated.

When the vibrato is not used the chorus effect corresponds to that produced by large church pipe organs when several pipes are simultaneously sounding the same nominal frequency. For theatrical and entertainment purposes where more tonal animation is desirable, the chorus effect may be increased by vibrato frequency modulating the two oscillators which produce signals of the same nominal pitch at vibrato frequencies either of different (preferably opposite) phase or of slightly different vibrato rates.

As previously indicated, various features of the

oscillators disclosed in this application are disclosed and claimed in other pending applications owned by the assignee of this application. In addition, it should be noted that the idea of frequency modulating the outputs of the oscillators by vibrato signals of different phase, or of slightly different frequency, is disclosed and claimed in my copending application Serial No. 223,376, filed April 27, 1951.

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

I claim:

1. In an electrical musical instrument having an output system, the combination of at least four electronic oscillators forming the tone signal sources for each octave within at least a two octave gamut, each oscillator having a tuning impedance whereby the oscillator may be tuned alternatively to produce signals having fundamental frequencies corresponding substantially to the pitch of two different tones of the tempered musical scale, each oscillator being tunable through a range of not more than four semitones, a pianoforte type keyboard comprising a plurality of playing keys, and circuits under the control of the keys to cause two of said oscillators to operate at the same nominal pitch and to cause transmission to the output system of the signals produced by both oscillators whereby all major and minor chords may be played with two oscillators supplying signals to the output system for most of the elements of the chord to produce a chorus effect.

2. The combination set forth in claim 1 in which the tuning impedances are of such values that when two oscillators are tuned to the same nominal pitch one will be sharp and the other will be flat with respect to the nominal pitch by between .25 per cent to 1.7 per cent.

3. In an electrical musical instrument having an output system, the combination of at least four electronic oscillators forming tone signal sources for each octave within the gamut of the instrument, each oscillator having a tuning impedance whereby it may be tuned to produce signals having fundamental frequencies corresponding substantially to the pitch of only two adjacent semitones of the tempered musical scale, a pianoforte type keyboard comprising a plurality of playing keys, circuits under the control of each key to change the effectiveness of the tuning impedance of at least one of said oscillators to cause it to oscillate at the same nominal pitch as another of said oscillators and thereafter to couple both oscillators to the output system.

4. In an electrical musical instrument having an output system and a plurality of playing keys; the combination of a plurality of oscillators, each oscillator having tuning means whereby it may be tuned to the pitch of any of four adjacent semitones of the tempered musical scale; means coupling the outputs of the oscillators to the output system; tuning circuits including switches operable by each of the keys to cause the tuning means of two of the oscillators to be tuned to the same pitch; additional switches operable by each of the keys; energizing circuits, each including one of said additional switches, to supply an operating potential to the two oscillators tuned by the operation of their associated keys, a chorus control element, and switches operated by said element and connected in two of the tuning circuits and in two of the energizing circuits associated with each oscillator.

5. In an electrical musical instrument having an output system, the combination of at least six electronic oscillators forming tone signal sources for each octave within the gamut of the instrument, each oscillator having tuning impedances whereby it may be tuned to produce signals having fundamental frequencies corresponding substantially to the pitch of four adjacent semitones of the tempered musical scale, a pianoforte type keyboard comprising a plurality of playing keys, and circuits under the control of each key to change the effectiveness of the tuning impedances of at least one of said oscillators to cause it to oscillate at the same nominal pitch as another of said oscillators and to cause transmission to the output system of the signals produced by both oscillators, whereby all major and minor chords may be played with two oscillators supplying signals to the output system for most of the elements of the chord to produce a chorus effect.

6. The combination set forth in claim 5 in which the tuning impedances of alternate oscillators comprise one capacitor and four separate inductance elements connected in series and the tuning impedances of the other oscillators comprise an inductance element and four capacitors of which at least three are connected in series.

7. The combination set forth in claim 6 in which the pitch ranges of the oscillators overlap by three semitone intervals.

8. The combination set forth in claim 6 in which the pitch ranges of the oscillators overlap by at least two semitone intervals.

9. The combination set forth in claim 6 in which means are provided to cause alternate oscillators to be tuned to the pitch of the highest of several simultaneously depressed keys associated with such oscillators, and in which means are provided to cause the intermediate oscillators to be tuned to the pitch of the lowest of several simultaneously depressed keys associated with them.

10. In an electrical musical instrument having an output system, the combination of a playing key; a plurality of oscillators, each oscillator having tuning circuit means whereby it may be tuned to the pitch of any of four different adjacent semitones of the tempered musical scale; means coupling the outputs of the oscillators to the output system; switches operable by the playing key to cause the tuning means of two of the oscillators to be tuned to the same pitch; two additional switches operable by said key; and two circuits, each including one of said additional switches, to supply an operating potential to the two oscillators tuned by the operation of said key.

11. The combination set forth in claim 10 in which there is provided a chorus control element, switches operable thereby in two of the tuning circuits of each oscillator to render it capable of being tuned only to either of two adjacent semitone pitches, and another switch operable by the chorus control element and connected in one of said two circuits which supply operating potentials to the oscillators.

12. In an electrical musical instrument having an output system, the combination of at least twelve electronic oscillators forming tone signal sources for each octave within the gamut of the instrument, each oscillator having tuning impedances whereby it may be tuned to produce signals having fundamental frequencies corresponding substantially to the pitch of any of three adjacent semitones of the tempered musical scale, a pianoforte type keyboard comprising a plurality of playing keys, and circuits under the control of each key to change the effectiveness of the tuning impedances of at least two of said oscillators to cause them to oscillate at the same nominal pitch as another of said oscillators and to cause transmission to the output system of the signals produced by the three oscillators, whereby all major and minor chords may be played with two oscillators supplying signals to the output system for most of the elements of the chord to produce a chorus effect.

13. The combination set forth in claim 12 in which three sources of vibrato frequencies of different rates are provided, and in which means are provided to couple the three vibrato frequency sources respectively to the three oscillators which are capable of oscillating at the same nominal pitch to cause their outputs to be frequency modulated at different vibrato rates.

14. The combination set forth in claim 12, in which the pitch ranges of the oscillators overlap each other, in a manner such that a series of oscillators will have means whereby they may be tuned, respectively, to the pitches of the notes set forth in the following series: C, C♯, and D; C♯, D, and D♯; D, D♯, and E; D♯, E, and F; E, F, and F♯. . . .

15. In an electrical musical instrument having an output system and a plurality of playing keys; the combination of a plurality of oscillators, each oscillator having tuning means whereby it may be tuned to the pitch of any of four different adjacent semitones of the tempered musical scale; means coupling the outputs of the oscillators to the output system; switches operable by each of the keys to cause the tuning means of two of the oscillators to be tuned to the same pitch; additional switches operable by each of the keys; and circuits, each including one of said additional switches, to supply an operating potential to the two oscillators tuned by the operation of their associated keys, whereby all major and minor chords may be played with two oscillators supplying signals to the output system for most of the elements of the chord to produce a chorus effect.

16. In an electrical musical instrument having an output system, the combination of at least twelve electronic oscillators forming the tone signal sources per octave within at least a two octave gamut, each oscillator having tuning impedances whereby the oscillator may be tuned alternatively to produce signals having fundamental frequencies corresponding substantially to the pitch of two adjacent semitones of the tempered musical scale, a pianoforte type keyboard comprising a plurality of playing keys and circuits under the control of each key to change the effectiveness of the tuning impedance of at least one of said oscillators to cause it to oscillate at the same nominal pitch as another of said oscillators and to cause transmission to the output system of the signals produced by both oscillators which are oscillating at substantially the same pitch.

17. In an electrical musical instrument having an output system, the combination of at least twelve electronic oscillators per octave within the gamut of the instrument, each oscillator having a tuning circuit including a capacitor which when connected in the tuning circuit will cause the oscillator to operate at a pitch one semitone lower than when the capacitor is not connected in the tuning circuit, a keyboard comprising a plurality of playing keys, a circuit under the control of each key for connecting said capacitor in the tuning circuit of one of the oscillators, and additional circuits under the control of said key to render effective said last named oscillator and another oscillator normally operating at the same frequency to transmit the signals produced thereby to the output system.

18. In an electrical musical instrument having an output system, the combination of at least four electronic oscillators forming the tone signal sources for each octave within at least a two octave gamut, each oscillator having a tuning impedance whereby the oscillator may be tuned alternatively to produce signals having fundamental frequencies corresponding substantially to the pitch of two different semitones of the tempered musical scale, each oscillator being tunable through a range of not more than four semitones, a pianoforte type keyboard comprising a plurality of playing keys, and circuits under the control of the keys to change the effectiveness of the tuning impedance of at least one of said oscillators to cause it to oscillate at the same nominal pitch as another of said oscillators and to cause transmission to the output system of the signals produced by both oscillators which are oscillating at substantially the same pitch, whereby all major and minor chords may be played with two oscillators supplying signals to the output system for most of the elements of the chord to produce a chorus effect.

19. In an electrical musical instrument the combination of oscillators C and C♯ each having a tuning circuit and each normally generating musical tone signals of pitches corresponding to the notes C and C♯ respectively, two playing keys for the notes C and C♯ respectively, a capacitor, means operable by the C key to connect said capacitor effectively in the tuning circuit of the C♯ oscillator, said capacitor having a value such that when connected in the tuning circuit of the oscillator it will cause it to oscillate one semitone lower than its normal C♯ frequency, means also controlled by the C key to cause transmission of the signal produced by both oscillators to the output system, an inductance element forming part of the C oscillator tuning circuit and of such value that when effectively disconnected from the tuning circuit of the C oscillator will cause it to oscillate one semitone above its normal frequency, means operable by the C♯ key effectively to disconnect said inductance element from the tuning circuit of the C oscillator, and additional means operable by the C♯ key to cause transmission to the output system of the signals produced by both oscillators.

20. In an electrical musical instrument having an output system, the combination of two oscillators each having a tuning circuit of such resonant frequency that the oscillators normally operate at frequencies corresponding substantially to the pitches of the notes C and C♯ respectively, and each having a reactive impedance, the reactive impedance of the C oscillator being normally connected so as to be ineffective in the tuning circuit and the reactive impedance of the C♯ oscillator being normally ineffective in the

tuning circuit of the C♯ oscillator, playing keys for the notes C and C♯ respectively, means operable under the control of the C key to render effective the reactive impedance of the C♯ oscillator, means operable under the control of the C♯ key to render ineffective the reactive impedance in the tuning circuit of the C oscillator, whereby upon depression of the C key both oscillators will be tuned substantially to the pitch of the note C and upon depression of the C♯ key both oscillators will be tuned substantially to the pitch of the note C♯, and means under the control of either key to cause transmission to the output system of the signals produced by both oscillators.

21. The combination set forth in claim 20, in which each of the oscillators includes a multielectrode vacuum tube having all of its electrodes except one electrode connected to suitable operating potential sources, and in which the means for causing transmission of the signals to the output system includes circuits for impressing an operating potential upon the excepted electrodes of both vacuum tubes.

22. The combination set forth in claim 20, in which each of the oscillators includes a vacuum tube having suitable operating potentials impressed upon all of its electrodes so as to render the oscillator operative, and in which the means for causing transmission to the output system of the signals produced by the oscillators includes means for coupling the output circuits of the oscillators to the output system.

23. In an electrical musical instrument having an output system, the combination of two oscillators each capable of generating electrical musical tone signals having fundamental frequencies corresponding to the pitches of either of two adjacent semitones in the tempered musical scale and each oscillator having an inductance-capacitance tuning mesh determinative of the frequency at which it normally operates, a pair of adjacent semitone interval keys, a switch operable by the lower key to connect a capacitor in the tuning circuit of one of the oscillators, the capacitor having a value such as to lower the frequency of oscillation by one semitone interval, a switch operated by the higher key effectively to disconnect an inductance element from the tuning circuit of the other oscillator, the inductance element having a value such that when it is not effectively in the tuning circuit the frequency of oscillation of the oscillator will be increased by a semitone interval, means for impressing an operating potential upon both oscillators when either key is operated, and means coupling the outputs of the oscillators to the output system.

24. In an electrical musical instrument having an output system, the combination of three oscillators each having a tuning circuit including a reactive element which may be rendered effective or ineffective in the tuning circuit, said oscillators being tuned to operate at the frequencies of the pitches of the notes C, C♯, and D, respectively, when said reactive elements are effective in the tuning circuit and to the frequencies of the notes C♯, D, and D♯, respectively, when said reactive elements are ineffective in their respective tuning circuits, a C♯ key, means operable by the C♯ key to render the reactive impedance of the C♯–D oscillator effective in its tuning circuit, additional means operable by the C♯ key to render both the C–C♯ oscillator and the C♯–D oscillator effective to transmit their output signals to the output system, means operable by the D key to render the reactive impedance of the D–D♯ oscillator effective in its tuning circuit, and additional means operable by the D key to render both the C♯–D and the D–D♯ oscillators effective to transmit signals produced thereby to the output system.

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