

Jan. 29, 1952

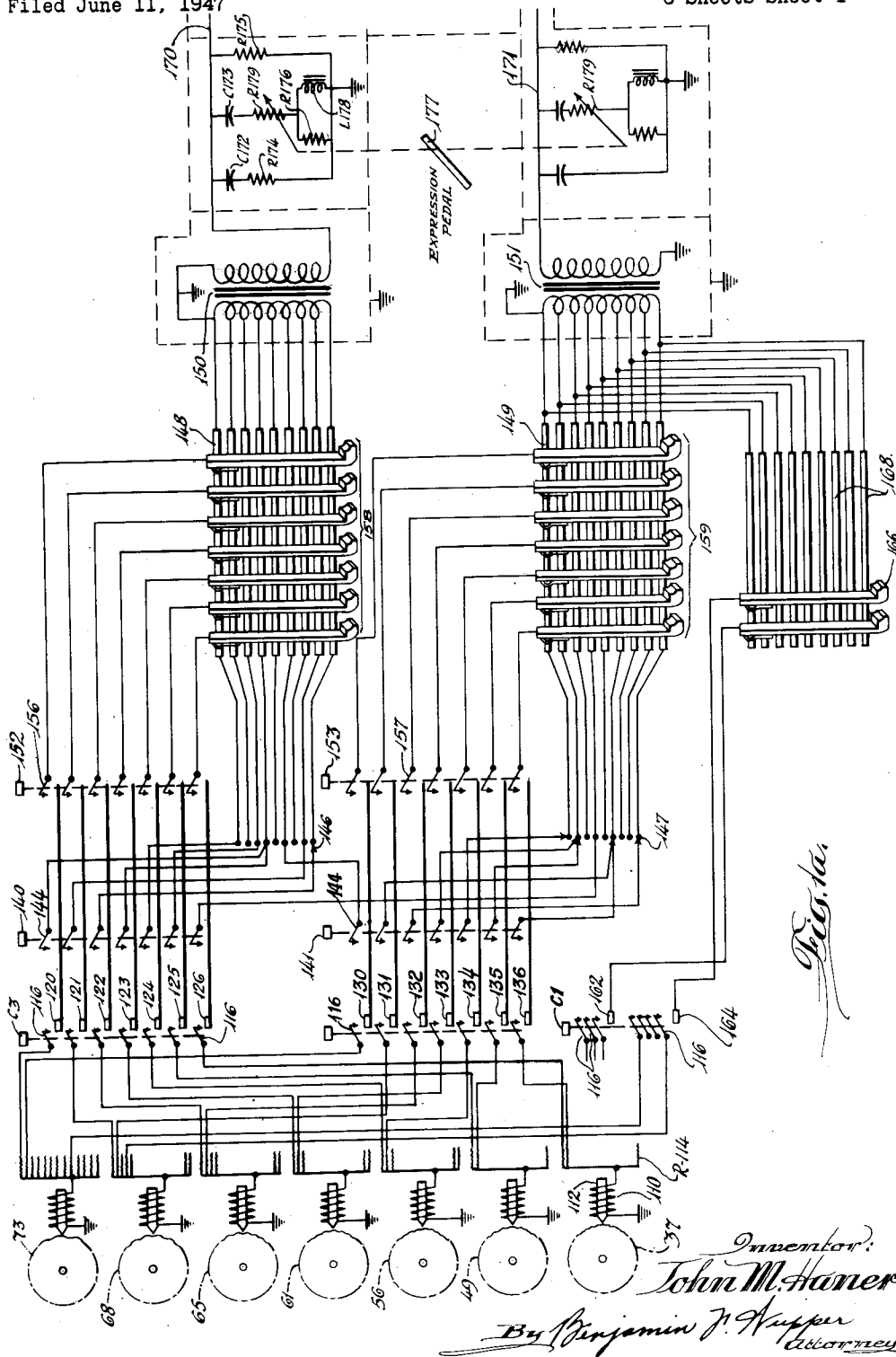
J. M. HANERT

2,583,566

ELECTRICAL MUSICAL INSTRUMENT

Filed June 11, 1947

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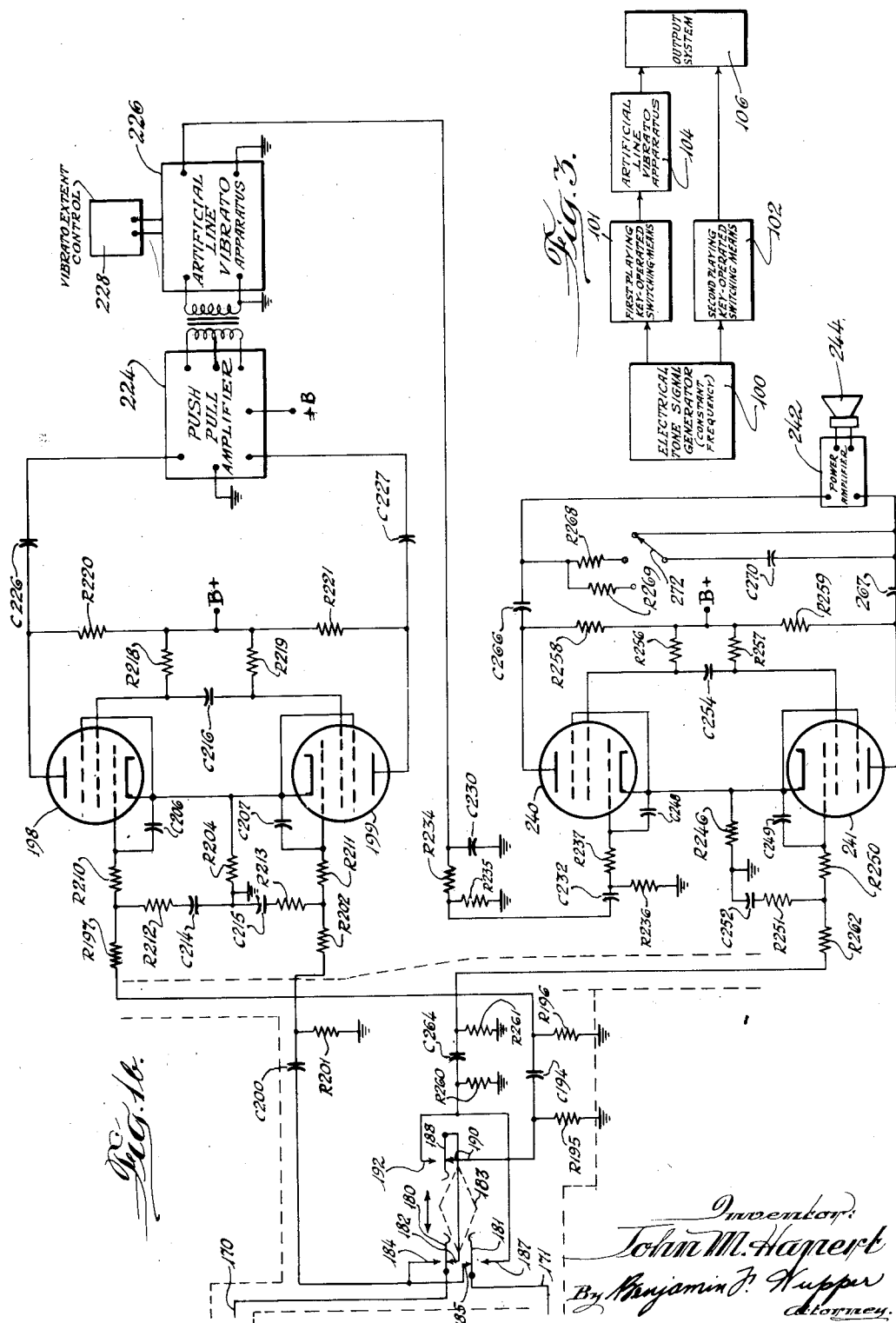
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ELECTRICAL MUSICAL INSTRUMENT

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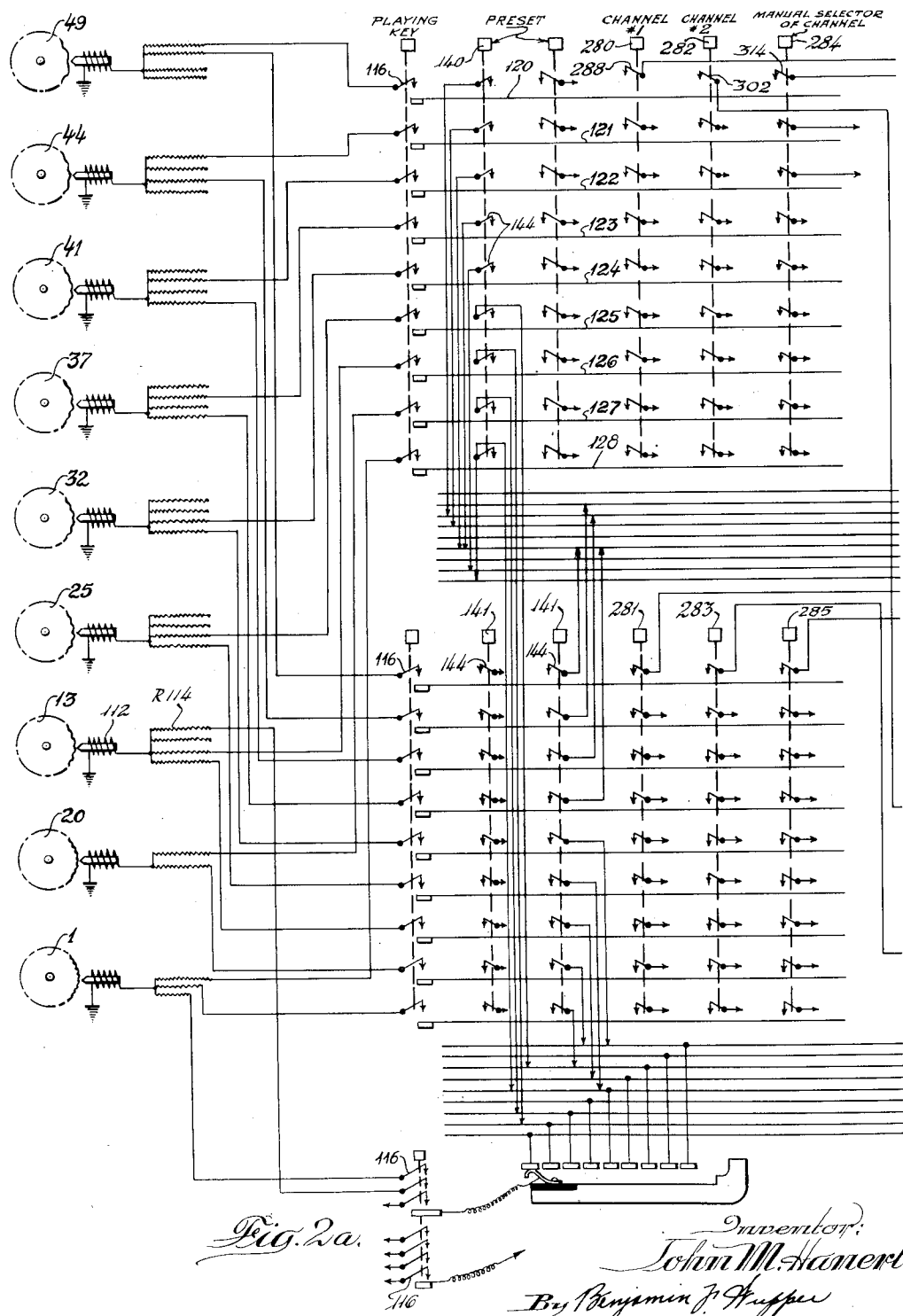
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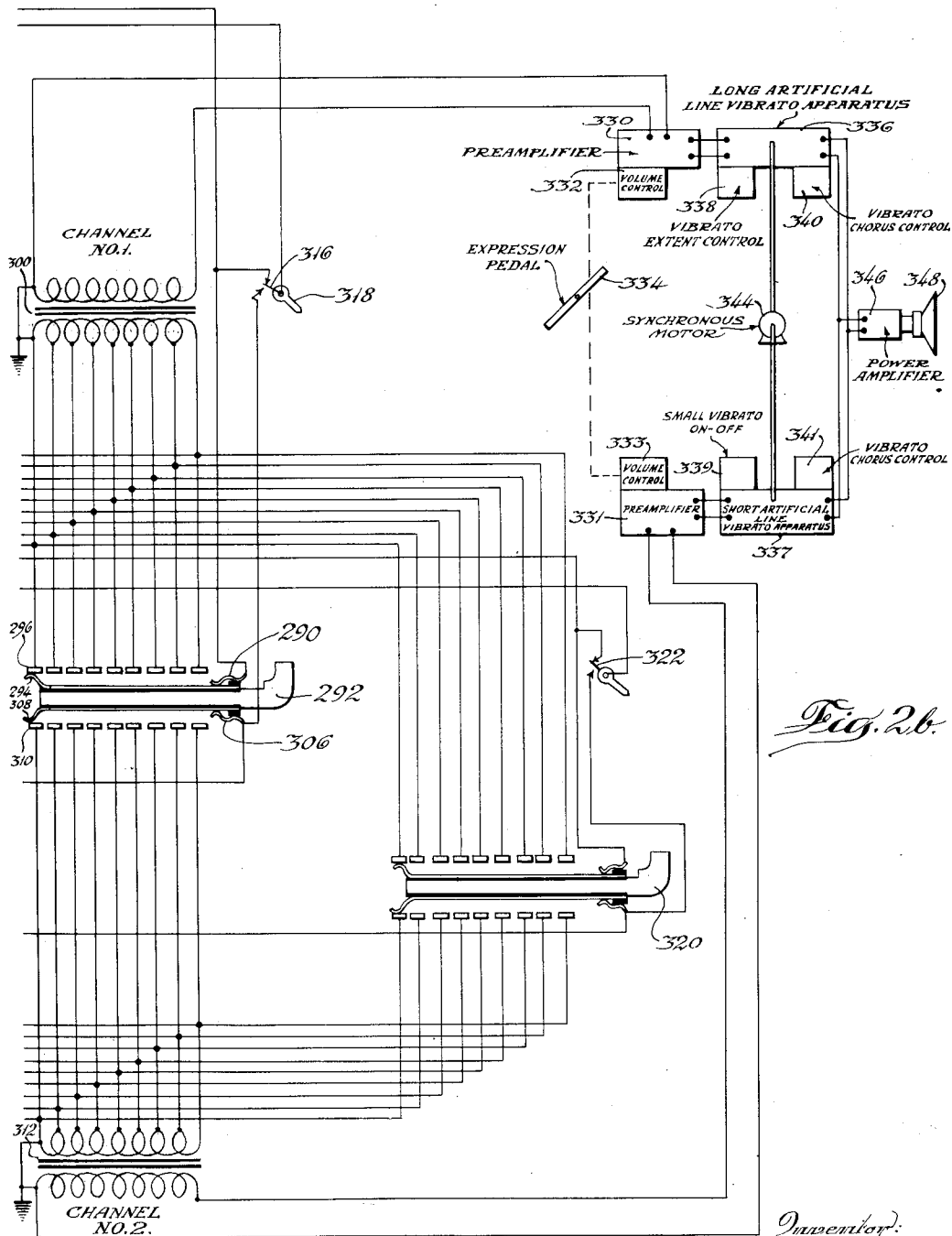


Fig. 2b.

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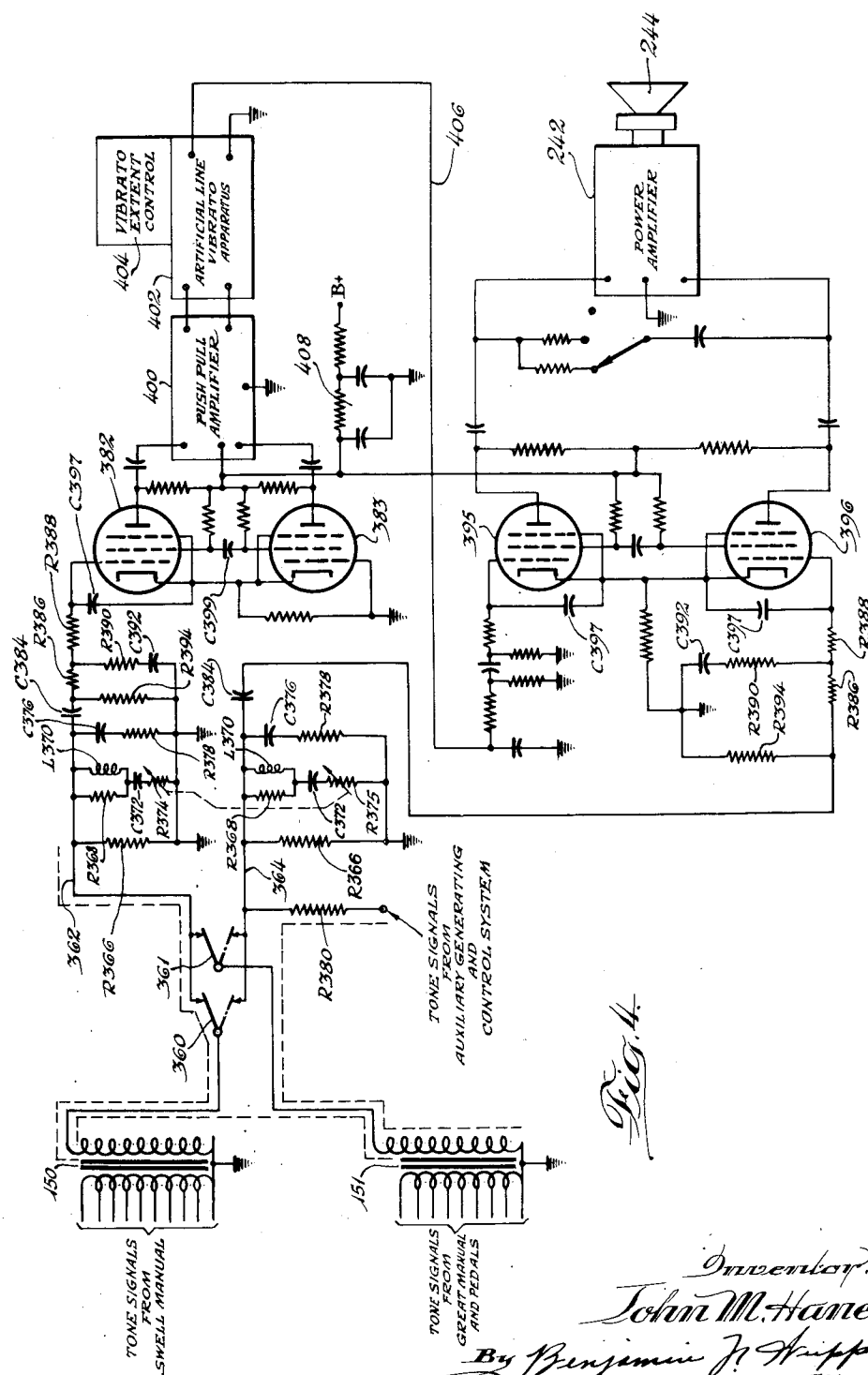
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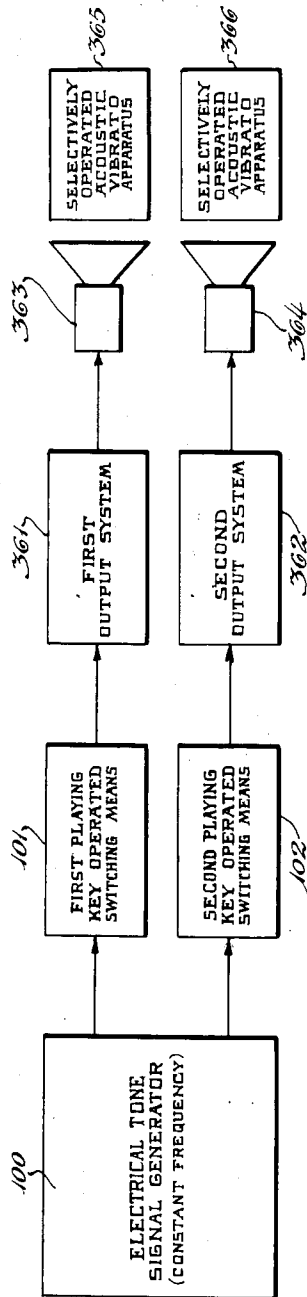


Fig. 5.

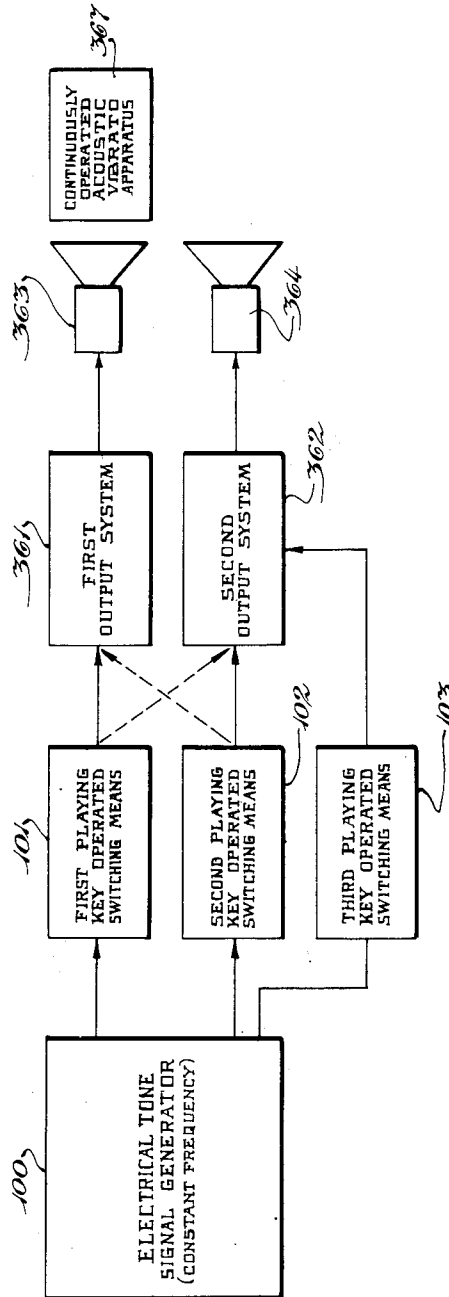


Fig. 6.

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UNITED STATES PATENT OFFICE

2,583,566

ELECTRICAL MUSICAL INSTRUMENT

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Application June 11, 1947, Serial No. 753,993

21 Claims. (Cl. 84—1.25)

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My invention relates to electrical musical instruments of the keyboard type such as organs.

The primary object of my invention is to produce with but a single set of tone generators the many extremely important and pleasing musical effects achieved by having vibratos of differing extents present in the various elements of a complex musical sound such as a solo with a polyphonic accompaniment. These differential vibrato effects are somewhat akin in their artistic aspects to theatre stage lighting. For instance, in a ballet scene in which there is a solo dancer with many subordinate dancers the dramatic and artistic effect of the solo dancer is seriously reduced when the stage with all its dancers is uniformly illuminated as compared with providing a spotlight for the solo dancer and maintaining the illumination for the subordinate dancers at a relatively low intensity. Similarly the effectiveness of a musical solo is very seriously reduced when both the solo and the accompaniment contain a uniformly large vibrato as compared with the superior effect of a large vibrato on the solo voice with a small vibrato, or no vibrato, at all, on the accompaniment. For instance, the effect of a large vibrato in a violin solo with contrasting non-vibrato harp accompaniment is one of the most effective instrumentations. Another equally effective instrumentation in the opposite sense is that of a non-vibrato clarinet solo played in contrast with a large vibrato polyphonic violin accompaniment.

The use of a large vibrato in all the tones of an organ produces a characteristic "theatrical" effect and while this effect is useful for certain highly animated types of music, it is nevertheless unsuited for more serious music and particularly for church and classical organ music. Furthermore, the effect of a heavy vibrato in all the tones tends to produce a vibrato frequency throbbing effect which is out of character for serious music. Experiment has shown that if the vibrato effect must be used on all of the organ tones for classical music it becomes necessary to so reduce the extent of the vibrato that its characteristic tonal warmth is almost absent. If, on the other hand, the accompaniment and pedal tones are sounded with no vibrato or with but a small vibrato, the solo tones may be sounded with a very large and rich vibrato. In the latter case, the vibrato becomes a highly artistic device not only as a means for providing emotional warmth to the solo, where it is wanted, but also as a valuable means for affording contrast and distinctness between the solo and the accompani-

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ment. The "throbbing" effect becomes negligible because only a small proportion of the acoustic energy is being vibrato frequency modulated.

The listener finds it very easy to distinguish the solo voice (even its pitch lies between other accompaniment notes which otherwise would mask it) if its vibrato is in contrast with the accompaniment. This is likewise true when the solo has no vibrato and is in contrast with the rich vibrato accompaniment. It appears that the ear is extremely sensitive to vibrato and can detect this effect even when it is associated with relatively soft tones in the masking presence of a large number of accompaniment tones provided that the latter are of different vibrato character.

In very large pipe organs, a differential effect has been sought, at great expense, by providing separate tremulants for the solo and accompaniment manuals. This has entailed the necessity of providing separate ranks of pipes for the solo and accompaniment. Likewise in the orchestra the differential vibrato effect is produced with separate instruments. Thus, in the past, the amount of primary generating equipment had to be doubled in order to produce the differential vibrato effect. According to the principles of the invention, a single set of generators (such as those disclosed in the electric organ shown and described in Patent No. 1,956,350 to L. Hammond) is used as a unitary tonal generating source for both vibrato and non-vibrato tones.

In order to achieve these highly desirable effects by this economical means the tones should be initially generated substantially devoid of vibrato and the vibrato producing means preferably takes a form similar to the electrical phase modulation vibrato apparatus described in my Patent No. 2,382,413. With this phase vibrato apparatus and a single set of generators having little or no vibrato in their generated outputs, the high desirable effects of differential vibrato are perfectly achieved. When one hears music played on this differential vibrato organ it is indeed hard to believe that the same primary generators are productive of a smooth steady non-vibrato horn solo tone as well as a scintillating vibrato string accompaniment. The undesired "unified organ" effect is completely obliterated and the listener senses a plurality of instrumental sources, as in an orchestral ensemble, even though there is present only a single tone generating means.

Another important object of my invention is to provide many new and interesting organ tone

qualities in which a differential vibrato is applied to the various harmonic overtones of the tone produced when playing but a single key. These harmonic vibrato effects are most readily achieved by using the above mentioned electric organ apparatus, in which separate intensity controls are provided for the individual partials making up the various tone qualities. When using the electrical phase modulation vibrato apparatus and the apparatus of this invention, it is possible selectively to sound any harmonic with a vibrato of controllable extent on either or both of the manuals without increasing the number of generators, key switches or otherwise materially increasing the cost of the instrument.

Under these conditions the musical tones produced strongly suggest a plurality of instrumental sources. For instance, a vibrato tone quality on all harmonics except the second (octave) strongly suggests the effect of orchestral strings with glockenspiel. This is because the glockenspiel is a relatively pure tone usually sounded at the octave and does not have vibrato. Similarly a non-vibrato fundamental in the presence of other vibrato overtones when played staccato strongly suggests the organ accompanied by a marimba or piano. Flute-like solo tones of exquisite beauty may be employed in which the fundamental has vibrato and the third harmonic has no vibrato, and vice-versa. Thus, having the vibrato selectively available on the various partials enables the organist to extend enormously the number of beautiful tonal effects obtainable.

Another important object is to provide an organ in which the vibrato effect is selectively available on the preset combination switches, making a single operation on the part of the player productive of a new harmonic series with vibrato preselection on all the partials.

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

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

Figure 2 and 2a together constitute a schematic wiring diagram of a second embodiment of the invention;

Figure 3 is a block diagram illustrating the broader aspects of the invention in a generalized form;

Figure 4 is a schematic wiring diagram illustrating another modified embodiment of the invention; and

Figures 5 and 6 are block diagrams illustrating the broader aspects of other modified forms of the invention.

The invention may be embodied in a wide variety of forms but is particularly adapted for use in electric organs of various types such, for example, as that illustrated in the patent to Laurens Hammond No. 1,956,350.

In Fig. 3 the invention is illustrated in generalized form. In its broader aspects the invention comprises an electrical tone signal generator 100 which is under the control of playing key operated switching means 101 and 102, the switching means 101 directing transmission of the signal produced by the generator 100 to an artificial line vibrato apparatus 104 and thence to an output system 106, while the switching means 102 causes transmission of the signal from the generator 100 directly to the output system 106. The artificial line vibrato apparatus is preferably of the type disclosed in my prior Patent No. 2,382,413 and the output system will in general

include an amplifier coupled either to a radio broadcasting system or to an electroacoustic translating means. The signal provided by the generator 100 is one of constant frequency during the playing of a note, that is, it includes little if any vibrato. The generator may, however, be one which is made to provide different frequencies upon operation of different playing keys. Its important feature is that the tone frequency signals which it produces are substantially free of vibrato. Thus the generator 100 may be a tunable vacuum or gas tube oscillator, a rotary or vibratory mechanical-electrical generator, or a pickup of a recorded signal (either phonographic, photoelectric, capacity, or electromagnetic). The generator 100 may be a single generator or a plurality of more or less independent generators of any of the above types, one for each tone frequency in the gamut of the instrument.

The playing key operated switching means 101, 102 in an elemental form may be simply two switches operated by one playing key or by playing keys of the same or different manuals. In most uses of the invention these switching means will assume one of the following forms: (a) Two keyboard manuals, one supplying all of its output through the vibrato apparatus 104 and the other supplying its output directly to the output system 106. In such system the solo part of the selection may be played on the manual which is connected to the vibrato apparatus while the accompaniment is played on the other manual with small or no vibrato, or vice versa. (b) The switching means may include a number of "pre-set" keys by which some of the partials of each of the tones controlled by a particular key are transmitted through the vibrato apparatus 104 while other partials are transmitted directly to the output system 106. (c) The switching means may include one or two manuals and a plurality of drawbars, one for each partial, the drawbars being operable selectively to transmit their respective partials to the output system either directly or through the vibrato apparatus 104.

Other switching devices and arrangements may be employed but the invention will be described herein as it is embodied in a two manual electric organ of the type disclosed in said Patent No. 1,956,350.

The artificial line vibrato apparatus is preferably of the type shown in Figs. 2, 2a, 2b and 2c of my prior patent, but may assume a variety of other forms some of which are shown in other figures of said patent. The fundamental requirement of this apparatus is that it be capable of changing a signal of constant audio frequency into a signal in which the frequency changes at a vibrato rate and to a vibrato extent without substantial distortion. It preferably includes selectively operated means to change the extent of the frequency or phase modulation, to produce a small, medium, or large vibrato effect. The vibrato apparatus will usually include an amplifier for the input signal, and a preamplifier for the output signal.

The output system 106 will usually comprise a number of stages of amplification provided with means to mix the two input signals without substantial distortion. It may also include volume and tone controls. In the usual use of the invention it will include one or more speakers.

In Fig. 1a the electrical generating system is illustrated as comprising generators having rotors 37, 49, 56, 65, 68 and 73 generating respectively the fundamental and second, third, fourth, fifth, sixth and eighth harmonics. These rotors

are preferably of soft iron having uniformly serrated peripheral edges and rotated at appropriate speeds so as to induce in pickup coils 110, wound on permanent magnets 112, the required frequency for the above mentioned partials of middle C. Each of the pickup coils 110 has one terminal connected to ground and has a plurality of relatively high valve decoupling resistors R114 connected to its other terminal. The resistors are suitably connected to switches 116 operated by a playing key C3 of the upper manual and similar switches 116 operable by a similar key of the lower manual. Some of the resistors R114 are suitably connected to the switches 116 of the bass pedal C1. Upon depression of the key C3 (and other keys) of the upper manual the switches 116 operated thereby respectively make contact with bus bars 120 to 126, while the key switches of the lower manual make contact with bus bars 130 to 136 respectively.

A plurality of preset combination keys 140, 141 are provided for each of the manuals, each of these keys operating switches 144. The switches 144 operated by key 140 make contact with bus bars 120 to 126, while those operated by key 141 make contact with bus bars 130 to 136 respectively.

Conductors attached to the switches 144 may be connected to any one of a plurality of binding posts 146, 147. The binding posts 146 are connected through busses 148 to suitably spaced taps on the primary of a matching transformer 150, while the binding posts 147 are connected through busses 149 to spaced taps on the primary of matching transformer 151. The upper manual is provided with preset key 152 while the lower manual is provided with a similar preset key 153, these keys being arranged to operate switches 156 and 157 respectively which cooperate with the bus bars 120 to 126 and 130 to 136 respectively. The switches 156 are connected to the drawbars 158 by which a contact is selectively made to any one of the busses 148, and similarly switches 157 are connected to drawbars 159 which operate selectively to connect the switches 157 to any one of the busses 149. The key switches 116 for the pedal C1 which control the transmission of the upper three harmonics, are adapted, upon depression of the pedal to make contact with a bus bar 162 while those for the lower order partials are adapted to make contact with a bus bar 164. The bus bars 162 and 164 are respectively connected to drawbars 166 which may be moved so as selectively to connect the bus bars 162 and 164 to any one of a plurality of busses 168, the latter being connected respectively to the taps on the primary of transformer 151.

It is important to note that the preset keys 140 and 152 for the upper manual are provided with a suitable mechanism which prevents more than one of these keys from being depressed at the same time, the mechanism also providing a latching means to maintain the key depressed. A similar mechanical arrangement is provided for the preset keys 141 and 153. It will be understood that, while for each manual only one preset key such as 140, 141 is shown in the drawing, any desired number may be provided. Likewise the keys 152, 153 and their associated drawbar mechanisms in circuits may be duplicated if desired.

The secondaries of transformers 150 and 151 are connected between conductors 170 and 171 respectively and ground, it being noted that these connections are made so that the signals on these two conductors which are derived from the same generator will be 180° out of phase.

Each of the conductors 170 and 171 is connected to ground through a suitable attenuating filter mesh, each mesh comprising capacitors C172, C173, resistors R174, R175 and R176, inductance L178 and variable resistors R179. The variable resistors R179 are shown as mechanically inter-connected for operation by a single expression pedal 177 (volume control), but if desired, may be provided with separate swell pedals or other suitable volume controls. The conductor 170 is connected to a movable switch arm 180 (Fig. 1b) while the conductor 171 is connected to a similar switch arm 181, the switch arm 180 normally engaging a contact 182 and movable by a cam actuator 183 to engage a contact 184. In a similar way the switch arm 181 normally engages contact 185 but may be cammed to engage a contact 187. The contact 182 is connected to a movable switch arm 188 which normally engages a contact 190, but when the mechanical actuator 183 is moved to the right the arm 188 is flexed into engagement with contact 192, and away from contact 190.

When the switch actuator 183 is in its central position, as shown in the drawings, a circuit is completed from the conductor 170, through switch contacts 180, 182, 188 and 190 to an attenuating network including capacitor C194 and resistors R195, R196 and R197 to the input of a pentode 198. Similarly, under these conditions, a circuit is completed from the conductor 171 through switch contacts 181, 185 to an attenuating network comprising capacitor C200 and resistors R201 and R202 to the input of a pentode 199.

The pentodes 198, 199 have their cathodes connected to ground through a common self-bias resistor R204, the cathodes being connected to their respective grids through capacitors C206 and C207 and their input circuits including control grid resistors R210, R211 respectively. The junction of resistors R197 and R210 is connected to ground through resistor R212 in series with a capacitor C214. The junction for resistors R202 and R211 is similarly connected to ground through resistor R213 and capacitor C215. The screen grids of the pentodes 198 and 199 are coupled by a capacitor C216 and are supplied with a suitable operating potential from a +B source through resistors R218 and R219 respectively. The plates of the pentodes 198 and 199 are connected to the +B source through load resistors R220 and R221. The signal on the plates of these pentodes is supplied to a push pull amplifier 224 through blocking condensers C226 and C227.

The output of the push pull amplifier 224 is illustrated as being transformer coupled to an artificial line vibrato apparatus 226 which, as previously mentioned, may be of the type shown in my prior Patent No. 2,382,413. This vibrato apparatus preferably is provided with a vibrato extent control 228, which is illustrated in my aforesaid patent, and which may comprise groups of multiple switches for changing the effective length of the artificial line, thereby changing the degree of phase and hence frequency modulation effected by the apparatus.

The output of the vibrato apparatus 226 is supplied through a suitable network including capacitors C230 and C232, resistors R234, R235, R236 and R237 to the grid of a pentode 240. The pentode 240 in cooperation with pentode 241 is effective to change the single ended output of the vibrato apparatus into a push pull output for supplying a power amplifier 242 which in turn may energize a speaker 244. The cathodes of the

pentodes 240 and 241 are connected to ground through a common self-bias resistor R246 while the cathodes are respectively connected to their control grids by capacitors C248 and C249. The input circuit for the pentode 241 also includes a series connection of its control grid to ground through resistors R250, R251 and capacitor C252. The screen grids of the pentodes 241 are coupled by a capacitor C254 and the screen grids and plates are supplied with suitable operating potentials from a +B source through voltage dropping resistors R256 and R257 and load resistors R258 and R259.

Thus under the conditions previously discussed, that is, with the switch actuator 183 in its central position the outputs of both manuals of the instrument will be transmitted through the artificial line vibrato apparatus and thus a vibrato effect will be obtained on the music controlled by both manuals.

When the switch actuator 183 is moved to the left the conductor 170 is connected to the input of pentode 199 by closure of the switch 180—184 and the conductor 171 is connected to the input of pentode 241 by virtue of the closure of switch 181—187. This latter circuit includes an attenuating network comprising resistors R260, R261 and R262 and series capacitor C264. When the switch is in this condition the signals supplied to the transformer 150 are transmitted to the pentode 199 which, due principally to the coupling of the screen grids of pentodes 198 and 199 by the capacitor C216, changes the single signal to a push pull signal suitable as an input for the push pull amplifier 224, and this signal, after passing through the vibrato apparatus 226, is impressed upon the grid of pentode 240. On the other hand, as previously indicated, the signals supplied to the transformer 151 and transmitted through conductor 171 are impressed upon the control grid of the pentode 241. By virtue of the fact that the connections to the secondaries of transformers 150—151 are reversed the signals, derived from any single generator, appearing on the control grids of pentodes 240 and 241 are in opposite phase and these tubes thus provide a suitable push pull input for the power amplifier 242, the signals being transmitted to this amplifier through blocking capacitors C266 and C267.

A simplified tone control comprising resistors R268 and R269 is adapted to be coupled across the input of the power amplifier 242 in series with a capacitor C270 by selective operation of a three position switch 272. Thus the signals produced by the rotating generators will appear in the power amplifier 242 and will be translated into sound by the speaker 244 with a vibrato effect added to the signals supplied through transformer 150, while the signals supplied through transformer 151 will appear as sound without the vibrato effect. Therefore the desired effect of contrast between the music played on one manual and that played on the other manual (or a contrast between various partials of tones) is readily obtained.

When the switch actuator 183 is moved to the right of its central position, it will be readily apparent that the conductor 170 is connected to the input of pentode 241 while conductor 171 is connected to the input of pentode 199. Thus, in general the music produced under the control of the upper manual will not have the vibrato effect whereas that produced under the control of the lower manual will have the vibrato added thereto.

It is essential that when the switch is displaced from its central position in either direction, that is, when only a part of the signals pass through the vibrato apparatus, that the signals appearing upon the control grids of pentodes 240 and 241 be of opposite phase and this result may be obtained, as previously indicated, by reversing the connections on the secondary winding of one of the transformers 150 or 151 or by utilizing an additional phase inverting device in some other portion of the circuit.

The apparatus and circuits shown in Figs. 1a and 1b may assume a number of variants and may be utilized with or without some of the components shown. For example, it is not essential that arrangements be made so that the conductors from the preset switches 144 be capable of selective connection to both the binding posts 146 and the binding posts 147, since results which are highly desirable from a musical point of view may be obtained if all the partials of a single complex tone under the control of a single key have the vibrato added or not, provided that the player has the option of having the vibrato in the complex tones produced under the control of the playing keys of the other manual.

The invention may be embodied in a more versatile form such as shown in Figs. 2a and 2b. In these figures there are illustrated 9 generators, numbers 1, 20, 13, 25, 32, 37, 41, 44 and 49 for generating respectively the sub-fundamental, sub-third, fundamental, second, third, fourth, fifth, sixth and eighth harmonics. These generators are provided with pickup coils 112 and decoupling resistors R114 previously described with the latter being connected to switch contact arms 116 of the upper and lower manuals as well as the pedal clavier in the manner previously described, and as further illustrated in the above mentioned Patent No. 1,956,350. The preset keys 140, 141 operate switches 144 in the manner previously described.

In addition to the playing keys and preset keys there are provided three control keys 280, 282, 284 for the upper manual and similar keys 281, 283 and 285 for the lower manual. The output system of the instrument includes two transmission channels designated as 1 and 2 in Fig. 2b. When key 280 is depressed the key switches 288 operated thereby will respectively connect the bus bars 120—128 to sliding contactors 290 associated with eight draw-bars 292. The contactor 290 maintains sliding contact with a contactor 294 which is adapted to engage any one of a plurality of busses 296 which are respectively connected to the taps of the primary of a transformer 300 for the channel No. 1 of the output system. Similarly, if key 282 is depressed to close its switches 302, the bus bars 120—128 will respectively be connected to sliding contactors 306 which are adapted to maintain contact with contactors 308 while the latter make contact with any of a plurality of busses 310 connected respectively to taps on the primary winding of a transformer 312 forming part of the channel No. 2.

When the third control switch 284 is depressed the switches 314 operated thereby respectively complete circuits from the bus bars 120—128 to switch arms 316 carried by a pivotal manually operable tablet 318. When this tablet is swung downwardly as shown in Fig. 2b, the switch arms 316 connect the bus bars 120—128 respectively to slide contactors 290 so that the signals on these bus bars are transmitted to the transformer

300 of channel No. 1, with each partial of an amplitude determined by the position to which its associated drawbar 292 is adjusted. On the other hand, when the tablet 318 is swung upwardly the bus bars 120—128 are respectively connected to the slide contactors 306 and thus the signals from these bus bars are transmitted to the primary of transformer 312 of channel No. 2, and their amplitudes will likewise be determined by the setting of the drawbars 292. Thus by simply operating the tablet 318 the tone signals present on the bus bars 120—128 may be made to be transmitted through either channel No. 1 or channel No. 2. As will hereinafter appear, each channel may be adjusted to be effective to add the vibrato effect to the signals or to transmit the signals without this effect.

The control keys 281, 283 and 285 are similarly connected to drawbars 320 and tablet operated switches 322, the construction and the operation of these circuits being the same as are controlled by keys 280, 282 and 284, as above described.

The secondary of transformer 300 is connected to a preamplifier 330 while the secondary transformer 312 is connected to a preamplifier 331. Each of these amplifiers may be provided with a volume control 332, 333 of any suitable construction, these volume controls being preferably operated by a single expression pedal 334, although separate expression pedals for each of these volume controls may be provided. The preamplifier 330 has its output coupled to a long artificial line vibrato apparatus 336 which preferably is provided with a control 339 whereby the extent of the vibrato may be changed as well as a vibrato chorus control. The output of preamplifier 331 is coupled to a relatively short artificial line vibrato apparatus 337, having a suitable on-off and extent control 339, and a chorus control 341. A synchronous or other constant speed motor 344 drives the scanning plates of both of the vibrato apparatuses 338 and 339, so that the signals appearing on their artificial lines will be picked up in phase and synchronism with one another. The vibrato chorus controls 340 and 341 may be of the type disclosed in Patent 2,509,923, granted May 30, 1950, upon my copending application Serial No. 653,195 filed March 8, 1946.

The output circuits of the two vibrato apparatuses are suitably coupled to an amplifier 345 which may drive a speaker 348.

The instrument shown in Figs. 2a and 2b is played in the customary manner except that the organist has at his immediate control the ability to change the tone from one having the vibrato to a similar tone without vibrato. Furthermore he has the ability to produce vibrato chorus in which both the vibrato and non-vibrato tone are superimposed to provide ensemble tonalities.

By suitably wiring the harmonic combinations to the preset keys he may also produce tonalities in which the vibrato effect is on only some of the various harmonics, and in this way he can produce a great many new and very interesting musical effects. When using one of these mixed non-vibrato vibrato combinations he may alter and reverse the vibrato and non-vibrato effects on the various harmonics by operation of vibrato controls 338 and 339. By interchanging the positions of these two controls he automatically changes the vibrato and non-vibrato arrangement on the preset combinations, that is, those partials which were previously vibrato now have no vibrato and vice-versa.

By operation of keys 280 and 281 the organist

may render the hand set drawbars 292 and 320 capable of selective registration to transmit the signal to channel No. 1 which has wide phase shifting characteristics and is therefore adaptable for large vibrato effects. In a similar manner operation of preset keys 282 and 283 causes the signals from their associated bus bars to be transmitted to channel No. 2 under the control of drawbars 292 and 320, which channel preferably introduces little or no vibrato. Thus having set the drawbars 292 and 320 to produce a certain tone quality, this quality is quickly changed either to include the vibrato effect, or not. Operation of preset keys 284, 285 enables the musician manually to select either channel No. 1 or channel No. 2 to be coupled to the drawbars 292 and 320, by shifting the tablet selectors 318 and 322.

In the previously described embodiments of the invention the expression pedal is illustrated as operating the volume controls for both channels. This is not necessary since a swell pedal may be provided for each of the volume controls so that the intensity of the tones produced under the control of the keys of one manual may be varied with respect to the intensity of the tones produced under the control of the keys of the other manual.

In neither of these embodiments is it feasible to supply to the amplifier tone signals from a more or less separate auxiliary instrument which is capable of supplying electrical tone signals containing a vibrato. In some electric organs it is desirable to utilize the output system of the organ for amplification and translating into sound the tone signals of the auxiliary instrument, such as those of chimes, harp, or bells, with an electric pickup, or an electric melody instrument such as shown for example in the prior patent to Hammond et al. No. 2,233,258. The auxiliary instrument may be controlled by switches operated by the organ playing keys and may be arranged so that the highest of a number of simultaneously depressed keys will control the pitch of the tone signals produced. Since such instrument will usually be one capable of producing vibrato tone signals, it would be undesirable to have its signals pass through the vibrato apparatus of the organ. In such instruments in which the auxiliary or melody instrument is to be played in conjunction with the organ I prefer the output system shown in Fig. 4.

In this arrangement the output signal from a special matching transformer 150 (for the output of the swell or upper manual) is connected to one pole of a single pole double throw switch 360, while the signal from the matching transformer 151 (for the great or lower manual, and pedals) is transmitted to a similar switch 361. When these switches are in their upper full line positions as shown, they connect the secondaries of the transformers 150 and 151 to a conductor 362, whereas when they are moved to their lower or dotted line positions they make connections with a conductor 364. The conductor 362 is provided with a suitable load and frequency response correction mesh comprising R366, R368, L370, C372, variable volume control resistor R374 as well as series capacitor C376 and resistor R378.

The output of the electrical melody instrument may be connected to the conductor 364 through a relatively high value (e. g. .5 megohm) decoupling resistor R380 and thus have its effective amplitude controlled by the expression or volume control resistor R375, of a load and frequency

responsive mesh similar to that connected to conductor 362.

The signal appearing on the conductor 362 is impressed upon the control grid of an amplifying pentode 382 through an input circuit including a capacitor C384 in series with resistors R386 and R388, the junction between the latter resistors being connected to ground through a series resistor R390 and capacitor C392, while the junction between C384 and R386 is connected to ground through a grid resistor R394.

The conductor 364 is similarly connected to the control grid of pentode 396, the circuit elements bearing similar reference characters. The control grids of pentode 382 and 395 and 396 are connected to their cathodes by capacitors C397.

In this embodiment of the invention it is practically necessary that the variable volume control resistor R375, for the signal on conductor 364, be mechanically connected to the corresponding variable resistor R374, since these controls are not particularly associated with either manual.

The screen grid of pentode 382 is connected to the screen grid of a pentode 383 by a coupling capacitor C399. The remaining elements of the circuits associated with pentodes 382 and 383 may be identical with those previously described with reference to the pentodes 240 and 241 of Fig. 1b. The output of the pentodes 382 and 383 is thus in push-pull, and is suitably coupled to a push-pull amplifier 400. The output of the amplifier 400 is connected to an artificial line vibrato apparatus 402 having a control 404 to determine the extent of the vibrato. This vibrato apparatus may include a preamplifier and its output is connected through a conductor 406 with the input circuit of a pentode 395. The pentodes 395 and 396 and their associated circuit elements may be identical with the pentodes 240 and 241 shown in Fig. 1b. Their output circuits are likewise similar to those of pentodes 240 and 241 and are illustrated as coupled to a power amplifier 242 and speaker 244. The B supply for the pentodes 382, 383, 395 and 396 is supplied from a B+ source through a suitable filtering mesh 408.

The output of the bass tone generators which is preferably transmitted through the output system without having the vibrato added will usually be connected to the taps on the primary winding of transformer 151.

The matching transformer 151 for the lower manual and pedals may be of conventional construction and the inductance of its secondary winding, at a frequency of approximately 40 c. p. s., is such as to resonate with capacitor C372 associated with the swell rheostat (and which is effective in the circuit when the swell rheostat R375 is at minimum value). Because of this resonance effect a sharply rising bass frequency characteristic is attained at low volume, and this is highly desirable for low pitch pedal tone. When the swell pedal is adjusted to maximum value of the resistor R375 the resistors R366 and R394 are effective to provide a load which has a slight falling frequency characteristic at the low frequency end.

In the operation of the instrument, the secondaries of transformers 150 and 151 are connected in parallel with each other by the switches 360 and 361, both when the vibrato is desired on both keyboards and when no vibrato is desired on either keyboard. If these transformers were ideal transformers, that is, if they had infinite inductance, it would be possible to connect the outputs of the two transformers in parallel

to a single load (resistors R166 and R394) without noticeable losses. However, due to the fact that the grid and pedal matching transformer 151 is purposely designed to have an impedance comparable to that of a load provided by resistors R366 and R394 at the low frequency end, it is necessary that means be provided for preventing noticeable losses in the bass frequencies when the two transformers 150 and 151 are connected in parallel. This is conveniently accomplished by making the secondary of transformer 150 of higher inductance than the secondary of the transformer 151. If the inductances of the secondaries of transformers 150 and 151 are in the ratio of about 3 or 4 to 1 the losses in the bass range will be less than 1 db when the two transformers are connected in parallel by the switches 360 and 361. In practice it has been found that making 6 of the 30 laminations of the core of transformer 150 of a high permeability hydrafined Permalloy in place of the usual steel laminations, will sufficiently increase the inductance of the secondary of transformer 150 to accomplish the desired result. When this is done the loss factor, when the two transformers are connected in parallel, is kept within 1 db and is not greatly changed throughout the adjustments of the swell resistors R374 and R375 because of the high parallel impedance of the secondary of transformer 150. At frequencies other than the bass frequencies the 70,000 ohm load provided by resistors R366 and R394 (each having a value of approximately 140,000 ohms) is the controlling impedance, and the parallel connection of the transformers produces no substantial loss. The load resistors R366 and R394 are of sufficiently low value that capacity effects due to the parallel connection of the transformers 150 and 151 is kept within 1 db.

The loss of 1 db is not ordinarily undesirable in the rendition of musical compositions. It will be noted that when both of the outputs of the transformers 150 and 151 are connected to the output system including conductor 362, the input of the non-vibrato system including the conductor 364 is loaded only by the 70,000 ohms provided by resistors R366 and R394, and the latter system may therefore be employed for the amplification of electrical tone signals supplied by auxiliary instruments, such as chimes, harps etc. whose tonal effects are best produced without vibrato but the volume or expression of which is to be controlled by the main expression pedal which controls the adjustment of R374 and R375. The outputs of such instruments may be connected to the conductor 364 through a decoupling resistor R380 of relatively high value such as $\frac{1}{2}$ megohm. Inasmuch as the load provided by resistors R366 and R394 is the controlling factor, the disconnection of both transformer secondaries from the conductor 364 will not have any appreciable effect upon the volume of the tone signals introduced through the decoupling resistor R380 from an auxiliary instrument. Thus the volume of the acoustic signal produced is substantially the same whether none, one, or both of the secondaries of transformers 150 and 151 are connected to the conductor 364.

Inasmuch as the low bass frequencies will not be transmitted efficiently through the transformer 150 the connection of the secondary of transformer 151 in parallel with the secondary of transformer 150 does not have any important effect.

From the generalized description of Fig. 3, as well as from the description of the specific em-

modiments of the invention it will appear that the invention may be embodied in a large variety of forms. For example it is not essential that the artificial line vibrato apparatus of my aforesaid Patent No. 2,382,413 be employed in the system. Instead, a vibrato phase shift apparatus operating acoustically and employing the Doppler effect may be used. Systems of this type are diagrammatically illustrated in Figs. 5 and 6.

In Fig. 5 the electrical tone signal generator 100, which generates tone signals of constant frequency, supplies these signals to the first and second playing key operated switching means 101 and 102, as in the embodiment of Fig. 3. The signals keyed by switching means 101 and 102 are respectively supplied to a first output system 361 and a second output system 362. These output systems include speakers 363 and 364 and selectively operated acoustic vibrato apparatuses 365 and 366. Each of the vibrato apparatuses 365, 366 may consist of rotating or oscillating elements in the form of vanes or horns located in front of the speaker so as cause apparent acoustic displacement of the source of sound, thereby to produce the vibrato effect by direct phase modulation of the sound waves. A vibrato apparatus of this type associated with a phonograph is shown in a patent to Myers 647,147 granted April 10, 1900. The mechanical rotating or oscillating part of such apparatus may be remotely controlled from the console and may be driven by an adjustable speed electric motor. The rotating or oscillating vanes or horns are preferably operated in the synchronism to prevent partial cancellation of their effects. Thus the player may have the vibrato effect added to the tones controlled by the switching means 101, or to the tones controlled by the switching means 102, or both, and he may therefore add materially to the variety of musical effects which may be produced from the tone signal generating system.

Since it is infrequent that the vibrato effect will be desired in the tones controlled by both of the key operated switch means, the apparatus may be simplified and its cost lessened by employing the apparatus diagrammatically illustrated in Fig. 6. For the sake of simplicity reference characters employed in the description of Fig. 5 are used to designate corresponding parts of Fig. 6. In Fig. 6 there is associated with the speaker 363 a continuously operated acoustic vibrato apparatus 367. It will be noted, however, that the switching means 101 and 102 may be connected to either the first output system 361 or to the second output system 362, or both of the switch means 101, 102 may be connected to either the first output system 361 or the second output system 362 as indicated by the full and dotted line arrows that connect these parts. In the system of the type shown in Fig. 6, the instrument, if it includes a pedal clavier, will employ a third playing key operated switching means which may be directly and permanently connected to the second output system. Thus the bass notes controlled by the pedal clavier will at all times be produced by the speaker 364 without the addition of the vibrato effect. The second output system 362 and its speaker 364 may thus be designed to transmit efficiently and at high amplitude the bass frequencies as well as the frequencies controlled by the switching means 101, 102, whereas the first output system 361 and its speaker 363 may be less powerful since these parts are never called upon

to transmit more than approximately $\frac{1}{4}$ as much energy as may be required of the second output system 362 and its speaker 364. Also by virtue of this arrangement the continuously operated acoustic vibrato apparatus 367 may be relatively small since it never operates upon the very low pedal frequencies.

From the foregoing it will appear that the invention is capable of embodiment in a wide variety of forms, each embodying the fundamental principle of utilizing a single source of constant tone frequency signals and, under the control of key operated switching means, transmitting such signals through two different channels or output systems in such manner that a vibrato effect may be introduced in the tones transmitted through at least one of these systems. The instrument preferably includes means for switching the signals so that the vibrato effect may be added by either or both of the channels.

Due to the fact that the tone signals transmitted through the two channels (one with and the other without the vibrato effect added) are derived from a single tone frequency source, the average frequencies of the tones to which the vibrato effect has been added will be the same as the corresponding tones to which the vibrato effect has not been added. There can therefore be no slow beats which might otherwise occur if there were differences between the average frequencies of the vibrato tones and the frequencies of the non-vibrato tones. Were such frequency difference present, the introduction of the vibrato effect would greatly magnify the acoustic beat phenomenon.

Prior to the present invention it has never been possible to produce from a single acoustic generator, or electro-acoustic generator, a single tone having some of its partials of sustained unvarying pitch while other partials have their pitch shifted to produce a vibrato effect. This effect can however readily be obtained in either of the two forms of the invention disclosed in this application merely by making the proper connections from the preset switches 144 to the desired busses which are connected to the output transformers of the two channels. This mixed or differential vibrato effect has great musical charm because of the chorus-like effect which is otherwise perceived only when a plurality of conventional orchestral instruments are sounded simultaneously.

It will be observed that except for the additional amplifier channels and the necessary additional switching devices, the instrument contains only the components of the usual electric organ of the type shown in the Hammond Patent No. 1,956,350. The number of generators, key circuits, preset keys and the like need not be increased to incorporate the present invention in an instrument of the prior art type. Thus the great improvements in tone qualities and versatility of the instrument are obtained at a relatively small additional cost. If it were attempted to produce equivalent effects without utilizing the principles of this invention, it would be necessary to provide two complete sets of generators, one generating the tone signal without the vibrato and the other with the vibrato and it would be necessary to double the number of switches under each playing key and also to provide elaborate means for maintaining the generators of the two generating systems in like phase. It is questionable whether this could be

accomplished in a commercially practical manner.

It will be understood that in the form of the invention shown in Figs. 1a and 1b the secondary of the transformer 150 might be connected directly (through a suitable network) to the control grid of pentode 198, and similarly, the secondary of transformer 151 could be directly connected to the control grid of the pentode 241 through an appropriate coupling network. Then the drawbar busses 148 and 149, instead of being connected directly to the taps of the primary of transformers 150, 151 respectively could be provided with suitable double throw switches so that these bus bars could be connected to the taps on either of the transformer windings. The switching means could be in the form of preset keys 152, 153, except that the switch arms of the preset keys would be respectively connected to the input taps of the transformers 150 and 151, while they would make contact with the groups of busses 148 and 149 respectively. The advantage of such latter construction is that the busses 169 for the pedals might be permanently connected to the taps of the non-vibrato transformer 151 because it is usually undesirable to introduce the vibrato effect in the tones controlled by the pedals. Signals from other tone generating systems might be permanently or selectively connected to the input of the transformer 151, such as microphones, melody instruments, etc. in which the organ vibrato effect would be undesirable but which it nevertheless would be desirable to control in intensity by the organ expression pedal.

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, the combination of a plurality of generators, each generating an electrical signal of constant frequency corresponding to a note of the musical scale, a plurality of bus bars, playing key operated switches for respectively connecting said generators with the bus bars, a pair of output channels, each channel having a transformer provided with a plurality of taps on its primary winding, preset keys operable to connect said bus bars to preselected taps on either of said transformer primary windings, an artificial line vibrato apparatus coupled to the secondary windings of each of said transformers, said vibrato apparatuses being mechanically coupled together to operate in phase and in synchronism, means for selectively rendering either of said vibrato apparatuses effective to produce a vibrato effect of predetermined extent in the signal supplied thereto, and means for amplifying and translating into sound the outputs of said vibrato apparatuses.

2. The combination set forth in claim 1 in which there is a common means for controlling the volume of the output of the two channels.

3. The combination set forth in claim 1 in which the instrument includes a plurality of

manuals and a plurality of drawbars, one for each partial for each manual, and in which one of the preset keys is provided with connections to render said drawbars effective.

4. The combination set forth in claim 1 in which there is provided a plurality of drawbars, each having means for selectively connecting one of the bus bars to any one of the taps on either of the transformer primary windings.

5. The combination set forth in claim 1 in which there are provided a plurality of drawbars, one for each of the bus bars, each drawbar having a pair of sliding contactors respectively engageable with two series of contacts respectively connected to the taps of the two transformer primary windings, and in which there is an independent manually operable switch to connect the associated bus bar to either of the sliding contactors.

6. In an electrical musical instrument, the combination of a plurality of sources of electrical musical tone frequency signals, a pedal clavier comprising a plurality of keys, a plurality of playing keys forming two manuals, a first and a second transformer, a load impedance, means for selectively connecting either or both of the transformers to the load impedance, signal collector busses respectively connected to the primary windings of said transformers, switches operable by the keys of one manual to connect said sources to the collector busses associated with the first transformer, and switches operable by the keys of the other manual and pedal clavier to connect said sources to the collector busses associated with the second transformer, the second transformer having a secondary impedance comparable to the load impedance at the lowest frequency of the signals controlled by the pedal operated switches, and the first transformer having an impedance which is high with respect to that of the second transformer at the lowest frequency of the signals controlled by the pedal operated switches, whereby there will be no appreciable attenuation of the tone signals respectively transmitted by the two transformers whether they are connected singly or in parallel to the load impedance.

7. In an electrical musical instrument having a generator of an electrical signal of relatively constant musical tone frequency, a vibrato apparatus capable of changing a constant frequency electrical tone signal supplied thereto into a tone signal incorporating a frequency shift vibrato, an output system coupled to said vibrato apparatus, and a plurality of playing key operated switching means, at least one of the switching means being operable to couple the generator to the vibrato apparatus to supply a tone signal to the latter, and at least another of said switching means being operable to couple the generator directly to the output system.

8. The combination set forth in claim 7 in which both switching means are operated by the same playing key.

9. The combination set forth in claim 7 in which the instrument includes two manuals, and in which one of the switching means comprises switches operated by a playing key of one manual and the other switching means comprises switches operated by a playing key of the other manual.

10. The combination set forth in claim 7 in which the generator generates a plurality of relatively constant tone frequencies usable to supply partials for the production of a com-

plex musical tone under the control of a single playing key, and in which the switching means operates to couple the generators of some partials to the vibrato apparatus and to couple the generators of the other partials directly to the output system.

11. In an electrical musical instrument having a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with one of the channels to introduce a frequency shift vibrato effect in the musical tones produced thereby, and a plurality of playing key operated switching means, at least one of the switching means being operable to couple one of the generators to one of the output systems and at least another of said switching means being operable to couple the same generator to the other output channel.

12. In an electrical musical instrument having a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a plurality of output channels, means associated respectively with said channels to introduce frequency shift vibrato effects of different characters in the musical tones produced thereby, and a plurality of playing key operated switch means, one of the switch means being operable to couple one of the generators to one of the output channels and at least another of said switch means being operable to couple the same generator to another output channel.

13. The combination set forth in claim 12 in which the means associated respectively with the channels are constructed and arranged to introduce vibrato effects of different extents.

14. The combination set forth in claim 12 in which the means for respectively introducing the vibrato effects in the two channels differ in the periodicity of the vibrato introduced.

15. The combination set forth in claim 12 in which the means associated respectively with the output channels to introduce the vibrato effect differ with respect to the periodicity and extent of the vibratos introduced thereby.

16. In an electrical musical instrument having a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with one of said channels to introduce frequency shift vibrato effects in the musical tones produced thereby, a pair of matching transformers, the secondaries of which have materially different inductance values, means for selectively coupling the matching transformers to the output channels, a pair of playing key operated switch means, one of the switch means being operable to couple one of the generators to one of the matching transformers and the other of said switching means being operable to couple the same generator to the other transformer.

17. In an electrical musical instrument including two playing manuals and having a plurality of generators of electrical signals of relatively constant musical tone frequencies, a vibrato apparatus capable of changing constant musical frequency electrical tone signals supplied thereto into tone signals incorporating a frequency shift vibrato, an output system coupled to said vibrato apparatus, and a plurality of

playing key operated switching means, the switching means operated by the playing keys of at least one manual being operable to couple generators to the vibrato apparatus to supply tone signals to the latter, and the switching means operated by the playing keys of at least another manual being simultaneously operable to couple the same generators directly to the output system.

18. An electrical musical instrument comprising, a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with one of the channels to introduce a frequency shift vibrato effect in the musical tones produced thereby, and a plurality of groups of playing key operated switching means, the switching means of at least one of said groups being connected to couple the generators to one of the output channels, and the switching means of at least another of said groups being connected to couple the same generators to the other output channel.

19. An electrical musical instrument comprising a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with one of the channels to introduce a frequency shift vibrato effect in the musical tones produced thereby, a plurality of groups of playing key operated switching means, means coupling the switching means to the generators, and selectively operable means coupling the switching means to either of the output channels.

20. An electrical musical instrument comprising, a plurality of manuals of playing keys, a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with the channels to introduce different characteristic frequency shift vibrato effects in the musical tones produced thereby, a plurality of switching means operable by the playing keys, means coupling the switching means to the generators, and selectively operable means for coupling the switching means to the output channels.

21. An electrical musical instrument comprising a plurality of generators of electrical signals of different relatively constant musical tone frequencies, a pair of output channels, means associated with one of the channels to introduce a frequency shift vibrato effect in the musical tones produced thereby, a plurality of groups of playing key operated switching means, means coupling the switching means to the generators, means coupling the switching means of one group to one output channel and means coupling the switching means of another group to the other output channel.

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