March 14, 1950 J. M. HANERT 2,500,820

ELECTRICAL MUSICAL INSTRUMENT

Filed Sept. 13, 1945 3 Sheets-Sheet 1

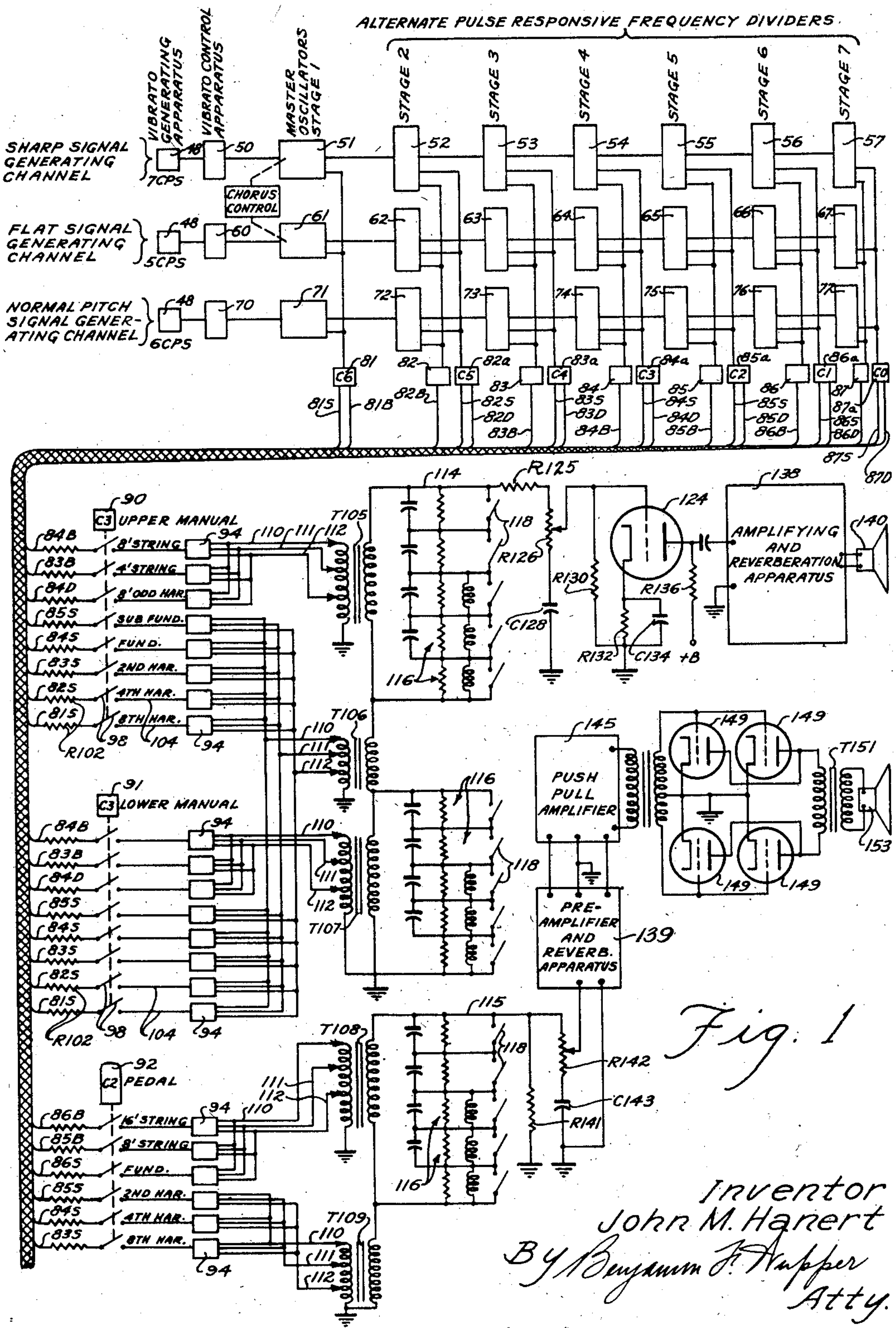
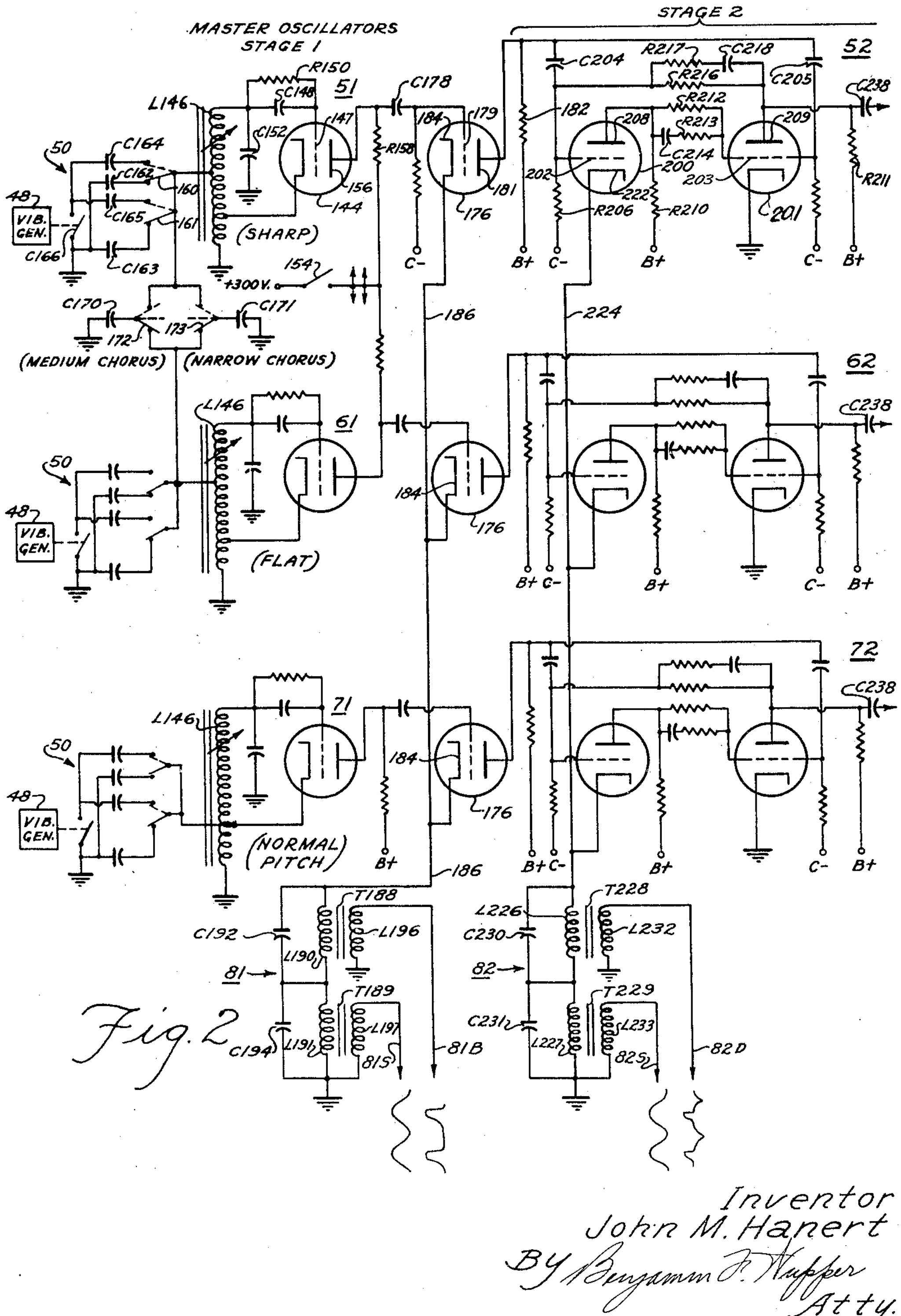


Fig. 1

Inventor
John M. Hanert
By Benjamin F. Wupper
Atty.


MASTER OSCILLATORS
STAGE 1
STAGE 2
(SHARP)
(FLAT)
(NORMAL PITCH)
(MEDIUM CHORUS)
(NARROW CHORUS)
VIB. GEN.
+300V.
Fig. 2
Inventor
John M. Hanert
By Benjamin F. Kupfer
Atty.

ELECTRICAL MUSICAL INSTRUMENT

Filed Sept. 13, 1945 3 Sheets-Sheet 3

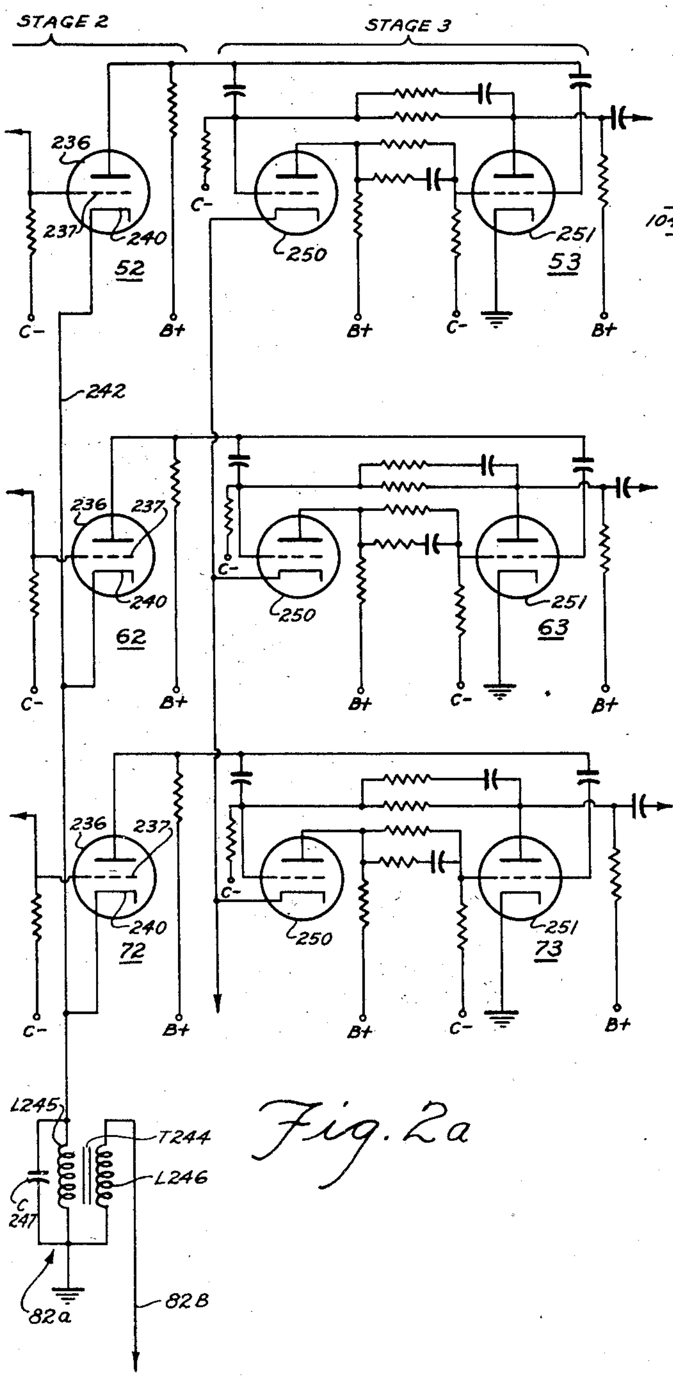


Fig. 2a

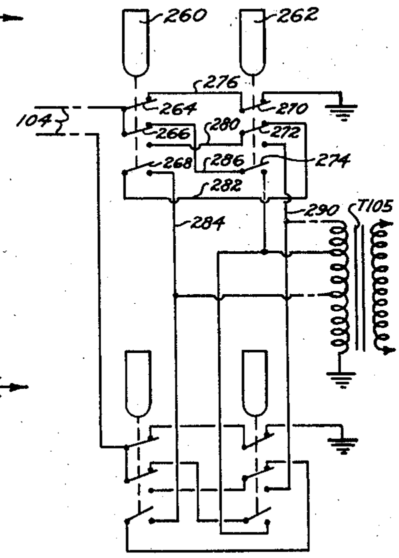


Fig. 3

Inventor
John M. Hanert
By
Atty.

Patented Mar. 14, 1950 2,500,820

UNITED STATES PATENT OFFICE

2,500,820

ELECTRICAL MUSICAL INSTRUMENT

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

Application September 13, 1945, Serial No. 616,079

12 Claims. (Cl. 84—1.19)

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My invention relates generally to electrical musical instruments and more particularly to electrical organs, melody instruments and other keyboard instruments.

In the past, electrical musical instruments have been provided with means for imparting various forms of tonal animation such as tremulants, that is, amplitude modulation devices, and vibratos, that is, frequency modulation devices. While it is true that these two effects, especially the vibrato, are productive of a certain degree of tonal warmth, it has been found that neither of them is a tonal substitute for the grand chorus effect of a very large number of the same kind of orchestral instruments sounding the same note simultaneously, nor of a large number of organ pipes sounding simultaneously, nor of a large chorus of voices.

To the listener and musician alike the chorus effect possesses an incomparable appeal because of its tonal grandeur. The random acoustic character of the chorus is unique among musical tonalities. In the chorus tonality the partials of a single tone are replaced by bands of numerous fundamental frequencies and bands of numerous harmonic frequencies.

Musical instrument builders have endeavored to produce the chorus effect by simultaneously sounding several slightly detuned generators such as the "celeste" strings of pipe organs, and reeds in accordions. Unquestionably the effect of sounding two or three slightly detuned audio frequency generators is a great advance over the effect of a single generator. However, the use of two or three generators does not constitute a solution of the problem of producing the highly desirable effect of a great many more instruments sounded simultaneously. Experiments show that while it is possible to achieve a pleasing "narrow" chorus effect with two or three generators, the effect becomes inharmonious or out-of-tune if an attempt is made to increase the width of the chorus effect by further detuning the generators. It has also been found that this inharmonious effect can be removed only by providing many more generators whose pitches are intermediate those of the first mentioned group. However, the cost of providing the necessary large number of individual generators for each note or key of the instrument is prohibitive for all practical purposes.

From an analytical aspect, the full chorus effect may be viewed as an extension of the vibrato effect. In both effects a band of frequencies is substituted for a single frequency. The physiological reason that the vibrato and chorus effects are pleasant is that more elemental organs of hearing, such as the nerve endings at the bases of the arches of Corti, are excited. However, each nerve ending is excited to a lesser degree

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than in the case of a single loud tone devoid of vibrato or chorus effect in which the energy is concentrated on but a few frequencies, resulting in but a few nerves being violently excited. The important differences between the vibrato and chorus effects are: (1) There are many more frequencies of comparable amplitude present in the wide chorus effect than in the wide vibrato effect; and (2) In the chorus effect, the listener's enjoyment of the music is not lessened by perceiving any regular or repetitive changes in pitch, or other pulsing beat effects, which are present in the vibrato.

The simple and novel apparatus of my invention produces an acoustic phenomenon which is identical with the true random wide chorus effect throughout periods of time of sufficient length to prevent the listener from perceiving the repetitious cycle. In other words, the acoustic phenomena occurring during one complete cycle are so complex and the cycle is of such long duration that the listener cannot identify corresponding cyclic events, and thus cannot assign any overall regular periodicity to the effect. This effect is produced by combining the outputs of as few as three generators each tuned to a slightly different pitch and each frequency-modulated at a different rate.

Experiments have shown that as few as three such frequency-modulated generators, carefully tuned to pitches lying in a relatively wide chorus frequency band, produce chorus effects of the maximum width desirable in music, and exhaustive tests have proved that these are equivalent, in the chorus effect, to as many as 20 simultaneously sounding melody instruments of the type shown in my prior Patent No. 2,254,284.

As is well known in the electrical art, frequency modulation is productive of a series of strong side band frequencies of decreasing amplitudes above and below the modulated frequency. In the musical art, frequency modulation is commonly called vibrato when produced by a single generator, and usually occurs at modulation rates in the order of 6 C. P. S. For a more complete discussion of the side band theory as applied to vibrato, reference may be had to my previous Patent No. 2,382,413. The degree of the vibrato effect is inherently limited because the side band frequencies are always separated by frequency increments equal to the rate of the vibrato, and the frequency increments are constant regardless of the width of the vibrato. Since the frequency increments are equal to the vibrato rate, the number of frequencies obtainable in a band of given width is limited. This fundamental limitation of the vibrato is obviated in the instrument of the invention by providing three or more generators which are frequency-modulated at different rates, such as 5, 6 and 7 C. P. S.

Under these conditions the various beats and other repetitious effects are of an extremely complex character due to the simultaneous generation of sound signals by the three frequency-modulated systems. Due to the fact that the modulating rates, as well as the modulated frequencies, are different, the various beat rates are mutually masked to such an extent that the ear is unable to detect a repititious cycle, and instead senses the tone as comprising a large number of randomly spaced frequencies in a band which is wide but in which there is no dissonance. The different sets of side band frequencies as thus generated by the three frequency-modulated systems are very great in number and tend to lie between each other and thus provide many frequencies of comparable amplitude in the band which, in turn, makes it permissible to detune the three generators to a considerable extent without causing inharmonious effects. On the contrary, they are then effective to produce a very wide and rich chorus effect of satisfying musical quality.

It is therefore the primary object of my invention to provide a novel apparatus for producing tones having a random chorus quality.

Another object of my invention is to provide an electrical organ in which complex as well as pure harmonic tones are generated.

Another object is to provide means for generating a complex odd harmonic series of tones with which the event harmonics may be synthetically combined.

Another object is to provide a chorus generator tuning system in which the degree of detuning may be easily and accurately determined by a zero-beat tuning method.

Another object is to provide a tone generating system capable of simultaneously generating a complex odd harmonic series, a string tone odd and even harmonic series, and a relatively pure sinusodial tone in which the phases of the three systems are substantially uniform and additive in all the notes of the instrument.

A further object is to provide a multiple channel vibrato apparatus in which vibratos of different rates are produced.

A further object is to provide a stable electronic alternate-pulse-responsive frequency divider tone generating system for organs.

A further object is to provide a simple and easily operated stop switch control mechanism.

A further object is to provide an electric organ by which, upon the depression of a single playing key, a tone of extremely complex quality may be produced.

A further object is to provide an improved output system for an electric organ in which some of the components of a complex tone may be quality controlled while other components thereof are not affected by such controls.

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

Figure 1 is in part a block diagram and in part a wiring diagram of the complete musical instrument;

Figures 2 and 2*a* together constitute a wiring diagram of a representative portion of the instrument; and

Figure 3 is a wiring diagram showing two stop switch units.

In Fig. 1 the generating system of the instrument is represented by blocks, whereas the output system is shown mainly in the form of a

schematic wiring diagram. As shown by the block diagram, the signal generating system comprises a sharp signal generating channel comprising the first horizontal row of blocks at the top of the diagram, a flat signal generating channel comprising the second row of blocks, and a normal pitch generating channel comprising the third row of blocks. The sharp signal generating channel comprises a frequency modulating vibrator apparatus 48 which supplies a modulating frequency, such as 7 C. P. S., to a vibrato control apparatus 50. The vibrato effects change in the frequency of the output of a master oscillator 51.

The master oscillator 51 supplies a controlling frequency signal to the second stage of a cascaded series of alternate pulse responsive frequency dividers 52 to 57, these divider stages each successively dividing frequency supplied thereto by 2. The flat signal generating system comprises a frequency modulating vibrato apparatus 48, operating at 5 C. P. S., a vibrato control 60, a master oscillator 61, and frequency divider stages 62 to 67. The normal pitch signal generating channel comprises a frequency modulating vibrato apparatus 48, operating at 7 C. P. S., a vibrato control 70, a master oscillator 71 and divider stages 72 to 77. Each of the master oscillators 51, 61, 71 supplies a signal to a transformer unit 81, which has two secondary windings, each having a grounded terminal and having their other terminals connected respectively to conductors 81S and 81B, the outputs differing in harmonic content. Conductor 81B provides a wave representing a string-like or brilliant (B) quality while the signal supplied to the conductor 81S is substantially a pure sine (S) wave.

Each of the divider stages such as the stages 52, 62 and 72 supplies a signal to a transformer unit 82, the secondary of which produces a brilliant signal in the conductor 82B. In a similar manner each of the divider stages 52, 62, 72 supplies a signal to a transformer 82A having two secondary windings, one supplying a sine wave to conductor 82S and the other supplying a wave representing the odd harmonic series to a conductor 82D.

Stages 53 to 57, 63 to 67, 73 to 77 respectively supply signals through transformer units 83 to 87 and 83A to 87A and provide signals of brilliant quality in conductors 83B to 87B, tone signals of sine wave form in conductors 83S to 87S, and signals representing the odd harmonic series in conductors 83D to 87D respectively.

The electric organ herein described is assumed to have an upper manual of playing keys, a lower manual, and a pedal clavier. For the purposes of illustration there is shown one playing key 90 representative of all of the keys of the upper manual, a key 91 representative of all of the playing keys of the lower manual, and a pedal 92 representative of the usual 32 pedals. The instrument would also include a plurality of stop switch units 94, each of which represents a pair of stop tablets for controlling the tone quality. These tablets and the switches operated thereby are shown in Fig. 3 and will hereinafter be described in detail. In addition, for determining which of a plurality of preselected tone qualities shall be used for either of the manuals, preset keys may be provided, in the manner shown in the patent to L. Hammond, No. 1,956,350, for rendering operative drawbars whereby the relative intensities of the individual components of the tone to be sounded may be controlled.

For purposes of illustration it is assumed that the outputs of the master oscillator 71 and of the divider stages 72 to 77 are respectively of the frequencies of the notes C6, C5, C4, C3, C2, C1 and C0 of the tempered musical scale, namely the following frequencies: 2093.00, 1046.50, 523.25, 261.626, 130.81, 65.406, and 32.703 C. P. S. It is also assumed that the keys 90 and 91 represent the note C3 while the pedal 92 represents the note C2. Each of the keys 90, 91 is arranged, upon depression, to close a plurality of key switches 98, herein illustrated as 8 in number. Each of the key switches 98 has connected to one pole thereof a decoupling resistor R102. In the switches operated by the playing keys 90, and 91 the resistors R102 are respectively connected to conductors 84B, 83B and 84D, 85S, 84S, 83S, 82S and 81S representing the eight foot string, the four foot string, eight foot odd harmonic series, subfundamental, fundamental, and second, fourth, and eighth harmonics of the note C3 respectively. The switches 98 make contact with bus bars 104, of which there is a group of eight for the upper manual, and a similar group of eight for the lower manual.

There are five matching transformers T105, T106, T107, T108 and T109, each having a primary winding, one terminal of which is grounded, and each having a plurality of taps illustrated as having conductors 110, 111 and 112 connected thereto. The stop switch units 94 are arranged to connect the bus bars 104 to selected conductors 110, 111 or 112. The switches 98 of the pedalboard are similarly adapted to be connected to selected conductors 110, 111 and 112 by the stop switch units 94 associated therewith.

The conductors 110, 111 and 112 may be more or less permanently connected to preselected taps on the transformers T105 to T109 or these conductors may be considered as representative of sliding contactors which may be individually adjusted to make contact with selected taps on these transformers.

The secondaries of the transformers T105 to T107 are connected in series between ground and a conductor 114, while the secondaries of transformers T108 and T109 are connected between ground and a conductor 115. The secondary of transformers T105, T107 and T108 are each adapted to have one of a plurality of tone quality determining meshes 116 connected in parallel therewith by opening one or more of the switches 118, one of which normally shunts each of these meshes.

It will be noted that only the bus bars 104 which carry complex wave form frequencies in the upper manual may be connected to the taps of the primary winding of transformer T105, only the complex wave bus bars 104 of the lower manual may be connected to the taps of the primary winding of transformer T107, and that only the complex wave bus bars 104 of the pedal clavier may be connected to the taps on the primary winding of transformer T108. The conductors 110, 111 and 112 for the upper and lower manuals, which conduct only sine wave signals, are connected to taps on the primary of transformer T106, while the corresponding conductors for the pedal clavier are connected to taps on transformer T109. The readily apparent reason for this is that the tone quality of the sine wave signal cannot be altered by means of filtering meshes such as meshes 116, and it is only the initially generated complex waves which may have their tone quality readily change by the use of such meshes.

The conductor 114 carries the combined signal from the three transformers T105 to T107 to a pre-amplifier triode 124 through a resistor R125 and volume control variable resistor R126. The resistor R126 is connected to ground through a bass compensation capacitor C128, while the grid or triode 124 is connected to ground through a grid resistor R130. The cathode of the triode 124 is connected to ground through a self-bias resistor R132 which has a by-pass condenser C134 in parallel therewith. The anode of pentode 124 is connected to a suitable source of plate current, indicated as a +B terminal, through a load resistor R136. The triode 124 is coupled to the input of an amplifying and reverberation apparatus 138, and the output of the latter is translated into sound by a speaker 140. The reverberation apparatus may be of the type shown in the patent to L. Hammond, No. 2,230,836. The reverberation apparatus is preferably provided with suitable control switches so that it may be used or not at will.

The resistors R102 are of high value relative to the output impedances of the transformer units 81, 82, 82A, 83, 83A, etc. and relative to the input impedances of transformers T105 to T109 so that completion of several circuits by the closure of switches 98 connected to the same transformer unit or transformer will cause substantially arithmetic addition of the signals and there will not be any appreciable feedback from one transformer unit to another through the several circuits which are completed upon closure of the key switches 98. The taps on each of the transformers T105 to T109 are preferably at geometrically increasing number of turns from the grounded ends of the transformers.

The secondaries of the transformers T108 and T109 are connected in series and coupled through conductor 115, resistor R141, volume controlling variable resistor R142, and bass compensation capacitor C143, to a preamplifier and reverberation control apparatus 139, the latter being coupled in push-pull to a push-pull amplifier 145. The output of the amplifier 145 is transformer coupled to the inputs of parallel push-pull triodes 149 forming a power amplifier, and the output circuit of the latter is coupled by a transformer T151 to a speaker 153. It will be noted that the push-pull power amplifier, comprising the triodes 149, operates as a class B amplifier, thereby providing high power output.

While the generating system employed may be of any desired type of electronic oscillator and cascaded frequency dividing system such, for example, as that shown in the patent to Laurens Hammond, No. 2,126,682, there is a great advantage in employing oscillators and alternate pulse responsive frequency divider systems of the type shown in Figs. 2 and 2*a*.

A preferred form of master oscillator such as the oscillator 51 comprises a triode 144 having a variable inductance L146, one terminal of which is connected to ground and the other terminal of which is connected to the grid 147 through a capacitor C148 having a grid leak resistor R150 in parallel therewith. A capacitor C152 is connected in parallel with the inductance L146. Upon closure of a switch 154 by means of the chorus control 49, the plate 156 of triode 144 is connected to a suitable source of plate voltage indicated as a terminal +300 v. through a plate load resistor R158. The closure of the switch 154 also applies operating plate voltage to the master oscillator 61 as well as the remaining master oscillators of the chorus generator channels. A pair of switches 160, 161, each has one pole connected to a tap on the inductance L146 and when in the full line position shown, connect this tap to ground through condensers C162 and C163. When in their dotted line positions the switches 160, 161 connect the tap on the inductance L146 to ground through parallel capacitors C164, C165 and a switch 166 which is opened and closed at a periodicity such as 7 C. P. S. by the vibrato switch operating apparatus 48.

The latter apparatus may comprise an electromagnetically energized vibratory reed such as disclosed in the patent to D. Hancock, Jr., No. 2,301,870, preferably operating in a manner to maintain the switch closed during only one half of the cycle. It will be clear that when the switch 166 is closed the capacitors C164, C165 will be effectively in the resonant tuning mesh of the oscillating triode 144, and that when this switch is open these capacitors are ineffective. The frequency of oscillation is therefore decreased when the switch 166 is closed and increased when the switch 166 is open. The value of the capacitor C162 is substantially one half that of C164, and C163 is one half that of C165. Thus, when, for example, the switches 160, 161 are in their full line positions, the frequency of oscillation will be the average of the two vibrato frequencies produced when these switches are in their dotted line positions. Three degrees of frequency modulation are available since the capacitors C164 and C165 are of different values. Thus, for example, when switch 161 only is in its dotted line position a narrow frequency modulation may be produced. When the switch 160 only is in its dotted line position a frequency modulation of medium width may be produced. When both switches 160 and 161 are in the dotted line positions a wide frequency modulation will be produced.

The master oscillators 61 and 71 are identical with the oscillator 51 except that the oscillators 51 and 61 are provided with additional means to facilitate their being tuned the desired degree sharp and flat relative to the normal pitch frequency generated by the oscillator 71.

To initially tune the master oscillators, the oscillator 71 is first tuned to its required pitch by adjustment of its variable inductance L146. It will be noted that there is provided a pair of capacitors C170, C171, each having one terminal grounded and its other connected respectively to single pole double throw switches 172, 173. With both of the switches 172, 173 in an intermediate position both capacitors C170 and C171 are ineffective. The flat oscillator 61 is then tuned to the same pitch as that of the oscillator 71 by adjustment of its variable inductance L146. Thereafter, either the switch 172 or the switch 173, or both of these switches (depending upon whether a medium, a narrow or a wide chorus effect is desired) are moved to full line position, thus including capacitors C170 or C171, or both, in the resonant mesh of oscillator 61 and thereby lowering its frequency of oscillation a desired amount.

To tune the oscillator 51 sharp the switch 172, or switch 173, or both of these switches, are moved to upper dotted line position so as to bring capacitor C170 or C171, or both of these capacitors, in the tuning circuit of oscillator 51. With the switches in the latter position the inductance L146 of oscillator 51 is adjusted to cause it to oscillate at the same frequency as the normal pitch oscillator 71. Thereafter, the switch 172, or 173, or both, are again moved to full line position with the result that the oscillator 51 will be sharp to substantially the same degree that the oscillator 61 is flat. The capacitors C170 and C171 together with their associated switches 172 and 173 thus form a simple and convenient means for tuning the sharp and flat master oscillators. This tuning operation, using the zero beat technique, is so simple that the user of the instrument may do it should it ever become necessary.

The oscillators have been found to be very stable in operation, so that such tuning should be necessary but very infrequently. It will be noted that the feedback circuits of these oscillators are through connection of their cathodes to taps on their inductances L146 somewhat above ground potential, sufficient to provide adequate feedback for self-oscillation.

The output circuit of the oscillator 51 is coupled to the input circuit of a rectifying and pulse sharpening triode 176 through a blocking capacitor C178 connecting the plate 156 of triode 144 with the grid 179 of triode 176. Negative grid bias is applied to the grid 179 through a resistor R180 connected to a suitable source of cutoff potential indicated as a terminal C—. The triode 176 is supplied with plate current through a load resistor R182 connected to a suitable source of plate voltage indicated as a terminal B+.

The outputs of the oscillators 61 and 71 are similarly coupled to rectifying and pulse sharpening triodes 176 and the cathodes 184 of all three triodes 176 are connected to a common conductor 186. This conductor connects the cathodes to ground through the transformer unit 81. This unit comprises a pair of transformers T188 and T189, the primary windings L190 and L191 of which are connected in series between the conductor 186 and ground, there being a capacitor C192 in parallel with the winding L190, and a capacitor C194 in parallel with the winding L191. Separate secondaries L196 and L197, respectively forming parts of the transformers T188 and T189, each has one terminal grounded and the other terminal connected respectively to the conductors 81B and 81S. Due to the filtering action of the capacitors C192, C194 and the inductances of transformers T188 and T189, the signal appearing on the conductor 81S will be substantially a sine wave while the signal appearing on conductor 81B will be a series of spaced positive peaks which will be in phase with the positive peaks of the sine wave on conductor 81S.

The alternate pulse responsive frequency divider stages are preferably of the form shown in my copending application Serial No. 519,838, filed January 27, 1944, now abandoned. Each of these stages comprises a pair of triodes 200, 201 having their grids 202, 203 connected to the plate 181 of triode 176 through capacitors C204 and C205. The grids 202, 203 are connected to a suitable source of negative grid bias indicated as terminals —C through grid resistors R206 and R207. The plates 208 and 209 of these triodes are connected to a source of plate current indicated as terminals B+ through load resistors R210 and R211. The plate 208 is connected to the grid 203 by a mesh comprising a resistor R212 having in parallel therewith a resistor R213 in series with a capacitor C214. Similarly the plate 209 is connected to the grid 202 through a resistor

R216 having in parallel therewith a resistor R217 in series with a capacitor C218. As more fully described in my aforesaid copending application, the triodes 200, 201 alternately conduct plate current as negative impulses are impressed upon their input circuits. It will be noted that the cathodes 220 of the triodes 201 are connected to ground whereas the cathodes 222 of the triodes 200 are connected to a common conductor 224. This conductor is connected to ground through the primary windings L226 and L227 of transformers T228 and T229 respectively comprising the transformer unit 82. The windings L226 and L227 have capacitors C230 and C231 connected in parallel therewith respectively. The secondary winding L232 of transformer T228 has one terminal grounded and the other terminal connected to the conductor 82D while the secondary winding L233 of T229 has one terminal connected to ground and its other terminal connected to its conductor 82S. Upon alternate pulses impressed upon the input circuit of triode 200, the cathode current will rapidly increase, and on the intermediate pulses, it will rapidly decrease, and the current wave on the cathodes 222 therefore tends to be of rectangular shape. Due to the filtering action of the meshes comprising the capacitors C230, C231 and transformers T228, T229, the signal appearing on the conductor 82S will be substantially a sine wave, while that appearing on the conductor 82 will be of complex shape as indicated in Fig. 2 adjacent the conductor 82D. The harmonic analysis of the wave of this shape shows it to be a fundamental with the long series of odd harmonics of progressively decreasing intensity without any even harmonics. The sound equivalent of this wave shape is very pleasing to the ear, its tone quality resembling that of the clarinet more than that of any other conventional musical instrument. Since this wave is produced only upon each alternate impulse supplied to the triodes 200, 201 it will be apparent that the frequency of the signals on the conductors 82D, 82S will be one half of that of the signals appearing on the conductors 81S and 81B.

A rectifying and pulse sharpening triode 236 (Fig. 2*a*) has its grid 237 connected to the plate 209 of triode 201 through a blocking capacitor G238. The triode 236 operates in a manner similar to the operation of the triode 176. The cathodes 240, for the triodes 236 of the divider stages 52, 62 and 72 are connected by a common conductor 242 to the transformer unit 82A which comprises a transformer T244 having a primary L245 and a secondary L246. A capacitor C247 is connected in parallel with the primary winding L245. L246 has one terminal grounded and the conductor 82B connected to its other terminal. Due to the rectifying action of the triode 236, the wave appearing upon the plate thereof will comprise sharp negative pulses which are impressed upon the input circuits of triodes 250 and 251 which form part of the third stage of frequency division, the circuit elements associated with the triodes 248 and 251 being the same as those shown in connection with the triodes 200 and 201. The values of some of the elements of the circuit may differ to accord with their different operating frequencies.

The subsequent stages 4 to 7 inclusive of each of the frequency generating channels are likewise similar to the second stage except for differences in the values of some of the components.

Referring to Fig. 3 each of the stop switch

units 94 comprises a "soft" stop tablet 260, and a "medium" intensity stop tablet 262. Stop tablet 260 operates a single pole single throw switch 264, a single pole double throw switch 266 and a single pole single throw switch 268. Stop tablet 262 operates a similar group of switches 270, 272 and 274. The switch arms of switches 264 and 266 are connected to one of the conductors 104 and when neither of the stop tablets 260 and 262 is depressed, the conductor 104 is connected to ground through the switch 264, conductor 276, the switch 270 and grounded conductor 278.

When it is desired to utilize the signal supplied over the conductor 104 at low intensity the stop tablet 260 only is depressed, thereupon completing a circuit from conductor 104 through switch 266, conductor 280, switch 272, conductor 282, switch 268 and conductor 284 to a tap on the associated matching transformer such as the transformer T105. The tap to which the conductor 284 is connected utilizes the lowest number of turns on the primary of the transformer and thus the output of the transformer is at low amplitude.

When it is desired to utilize the signal on conductor 104 at medium intensity the stop tablet 262 only is operated, whereupon, the signal is transmitted from the conductor 104 to the transformer T105 through switch 266, conductor 286, switch 274, and conductor 288 to the intermediate tap on the primary of T105 thereby causing the signal in the output of this transformer to be at medium amplitude.

When the signal on conductor 104 is to be utilized at full amplitude, both stop tablets 260 and 262 are depressed, whereupon the signal from the conductor 104 flows through switch 266, conductor 280, switch 272 and conductor 290 to the ungrounded terminal of the primary of T105.

By virtue of the use of this type of stop switch unit the amplitudes of the complex and sine wave components of each tone may be individually controlled in any one of three degrees of intensity. Thus a large variety of extremely complex qualities may be selected and made available for each of the manuals and for the pedal clavier. In addition, the quality may further be controlled by selective operation of the switches 118 to render effective one or more of the filter sections 116.

Because of the use of the decoupling resistors R102 cross-modulation effects are negligible and there is no appreciable signal feedback to the generating system through the key completed circuits. Therefore, any desired number of keys of either or both manuals, and the pedal clavier may be operated simultaneously without interference.

It will be noted that the tablet switch units 94 of both upper and lower manuals, which control the substantially sine wave signals from the generating system, are connected to the transformer T106 while the tablet switch units 94 of the upper manual which control the complex quality outputs of the generating system are connected to transformer T105. Similarly the tablet switch units 94 of the lower manual controlling the complex waves are connected to T107, and the tablet switch units 94 for the pedal controlling the complex waves are connected to T108. Inasmuch as each of these latter three transformers has tone quality filtering meshes 116 associated therewith, the complex quality tone signals may have their harmonic content substantially altered by appropriate operation of the switches 118. Thus the tone qualities available on the two manuals, as well as on the pedal clavier, may be individually selected, making it possible to utilize a registration technique substantially like that employed in playing the pipe organ.

The instrument is played in the usual manner, the musician selecting desired tone qualities by the operation of the stop tablets 260, 262. The quality of the components other than the sine wave components may be varied from time to time by selective operation of the tone control switches 118.

Due to the fact that there are three signal generating channels by which a chorus of any one of three selective widths may be obtained, and due to the fact that each of the three generating channels has a different vibrato periodicity, it is clear that by depression of a single key a tone of utmost complexity may be produced. The tone is equivalent to that produced by a large number of mechanical musical instruments simultaneously playing the same note, such, for example, as the sound produced by a large orchestral string section when all the musicians are playing the same note. The richness and harmonic complexity of the tones produced far exceed those previously obtainable from any other single musical instrument known to applicant.

Since the three signals (sine wave, brilliant, and odd harmonic series) are in phase, they will be additive when used simultaneously. It will be noted that in synthesizing a tone quality by the operation of the stop switch units 84 controlling the sine wave output signals of the generating system, only even harmonics are utilized so that it is not necessary to "borrow" odd harmonics of the tempered scale from other generators. Instead, a signal comprising the exact odd harmonic series signals may be synthesized with the sine wave even harmonic signals to produce substantially any desired tone quality.

As previously pointed out, the output signals of the generating system may comprise solely the output of the normal pitch channel, or may comprise the outputs of all three channels, by selective operation of the chorus control 49 (switch 154, Fig. 2) which renders operative the flat and sharp signal generating channels.

Furthermore, the player may, by appropriate operation of the switches 172, 173, determine the width of the chorus effect desired, and, by appropriate operation of switches 165, may control the vibrato apparatus. By virtue of the fact that the normal pitch, sharp pitch and flat pitch generating channels may each have a different vibrato rate, the overall effect of tone produced is extremely complex and the musical tones produced are comparable in richness and warmth to those produced by choruses of instruments such as those of the string section of a symphony orchestra.

The three generating systems may be tuned so that two of them are sharp and flat respectively relative to the third generator by amounts in the order of 1% of the pitch of the note. The degree of sharpness or flatness to which the generating systems are tuned should not be more than 1.7%, but may be considerably less than 1%, such as .25%, and still produce a desirable chorus effect, although of course not as pronounced as when the frequency difference is greater.

The vibrato rate is preferably in the range of from 5.5 to 7.5 C. P. S. and the extent of variation in frequency due to the vibrato is preferably 1% of the pitch of the note. However, the pitch change due to the vibrato effect may vary somewhat from this percentage and still produce musically advantageous results. A frequency change due to the vibrato of from .25% to 1.5% above and below the average frequency may be employed.

While I have shown and described a particular embodiment 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 generating system producing frequencies of the musical scale at normal pitch, a generating system producing frequencies slightly sharp, a generating system producing frequencies slightly flat, means individual to each generating system and coupled therewith for frequency modulating the signals produced thereby to an extent to cause the introduction of the vibrato effect, each of said last named means operating at a rate differing from that of the others, the respective rates being approximately 5, 6 and 7 cycles per second, and means for combining the signals produced by the three generating systems and translating the combined signal into sound.

2. An electrical musical instrument comprising three generating systems, each system including a plurality of generators of different musical tone frequencies, the first system generating electrical signals respectively of the nominal frequencies of the tempered musical scale, the second system generating electrical signals which are respectively sharp relative to the nominal frequencies of the musical scale by 0.25 to 1.7 percent, and the third system generating signals which are respectively flat relative to the nominal frequencies of the musical scale by 0.25 to 1.7 percent, the extent to which the second system is sharp and the third system is flat being sufficient to produce a readily perceptible chorus effect, vibrato means individual to each generating system to frequency modulate the signals generated thereby at slightly different rates within the range of 5 to 7.5 cycles per second, an output system, and key operated means for causing simultaneous transmission to the output system of signals from corresponding generators of the three generating systems.

3. An electrical musical instrument comprising electrical signal generating systems, each capable of producing signals of all of the notes of the musical scale within the gamut of the instrument, the frequencies of the signals generated by at least two of the systems differing from the standard frequencies of the tempered musical scale by 0.25 to 1.7 percent to produce a wide chorus effect when combined and translated into sound, means for frequency modulating the signals produced by the generating systems at different vibrato rates, and selective means for combining the signals from the generating systems and translating the combined signal into sound.

4. A quality control apparatus for selectively connecting a signal carrying bus bar to one of four different amplitude determining terminals, comprising a pair of manually operable elements, a plurality of switches operated by each element,

four circuits for connecting the bus bar respectively to said four terminals, each circuit including at least one switch operated by each of said elements, said circuits being completed respectively when neither of the elements is operated, when the first of the pair of elements is operated, when the second of the pair of elements is operated, and when both elements are operated.

5. In a generating system capable of producing musical tone frequencies of complex wave form and of sine wave form, a pair of matching transformers having tapped primary windings, a plurality of bus bars, key operated switches for selectively connecting said signal generators to said bus bars, means to connect sine wave signal collecting bus bars to selected taps of the primary of one of said matching transformers, means to connect the bus bars carrying complex wave signals to selected taps of the primary of the other of said transformers, a plurality of selectively coupled filtering meshes associated with the latter transformer, and means for combining the outputs of both of said transformers and translating the combined signal into sound.

6. In an electrical musical instrument having a signal generating system producing complex quality and substantially sine wave signals of octave relationship, signal collecting bus bars, playing key operated switches for connecting the generating system to the bus bars, a pair of transformers having tapped primaries arranged to be coupled to the bus bars, one of said transformers being arranged to be coupled to bus bars carrying complex quality representing signals, the other to bus bars carrying signals of substantially sine wave form, a filtering mesh having a plurality of adjustable impedance varying filtering means associated with the first transformer, and means for amplifying and translating into sound the combined signals derived from both of said transformers.

7. In an electrical musical instrument, the combination of three generating channels, each comprising a master oscillator and a plurality of frequency divider stages connected thereto in cascade so as respectively to generate frequencies corresponding to the pitch of corresponding notes in the successive octaves of the musical scale, one of said channels generating signals of normal frequency and the other two channels generating signals respectively sharp and flat relative to the normal pitch frequencies, each of said channels including means for frequency modulating the frequencies generated thereby, said frequency modulating means operating at different rates within the range of 4.5 to 7.5 cycles per second, means for combining the signal outputs of corresponding stages of said generating channels, and playing key operated switch means for selectively transmitting signals from a plurality of said stages to the output system of the instrument.

8. In an electrical musical instrument having an output system, the combination of three signal frequency generating systems, each generating all of the frequencies corresponding generally to the notes of the musical scale, one of said systems generating signals of the frequencies of the musical scale with substantial exactness and the other two systems generating signals respectively sharp and flat relative to the substantially exact frequencies, each of said systems including means for frequency modulating the signals generated thereby, said frequency modulating means operating at different rates within the range of 4.5 to 7.5 cycles per second, and playing key operated switch means for selectively transmitting signals from the generating systems to the output system of the instrument.

9. In an electrical musical instrument having a plurality of frequency generating channels, each channel generating octavely related frequencies, means for frequency modulating the signals produced in said channels at a rate in the order of 6 cycles per second and to an extent in the order of 1.5% of the modulated frequency, an output system for the instrument, key controlled means for selectively connecting corresponding generators of the several channels to the output system, and means for selectively adjusting one of the channels to generate frequencies in the order of 1% higher than another of the channels and a third channel to generate frequencies in the order of 1% lower than those generated in the first channel.

10. In an apparatus for controlling the degree of coupling of a signal carrying conductor with an output device, in which the device has three input terminals, each for a different degree of attentuation of the signal in the output device, the combination of two manually operable tablets, a break and make switch and a make switch operable by each of the tablets, said signal carrying conductor being connected to one of the break and make switches, and conductors connecting at least two of said switches of different tablets in series between the signal conductor and the input terminals, the connections of the conductors being arranged to cause the signal conductor to be connected to the high attenuation terminal when one of the tablets is operated, to connect the signal conductor to the intermediate attenuation terminal when the other tablet is operated, and to connect the signal conductor to the low attenuation terminal when both switches are operated.

11. The combination set forth in claim 10 in which each tablet is provided with an additional break switch normally connected in series between the signal conductor and ground.

12. An electrical musical instrument comprising, a plurality of electrical signal generating systems, each capable of providing a signal for each note within the gamut of the instrument, the frequencies of the signals for corresponding notes generated by said systems differing from each other by from 0.25 to 1.7 percent to produce a perceptible chorus effect, means for frequency modulating the signals produced by the generating systems at different vibrato rates between 5 to 7.5 cycles per second, an output system, a plurality of playing keys, and means operated by each key to select corresponding frequency signals from each of the generating systems and to transmit the signals to the output system.

JOHN M. HANERT.

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