

July 2, 1946.

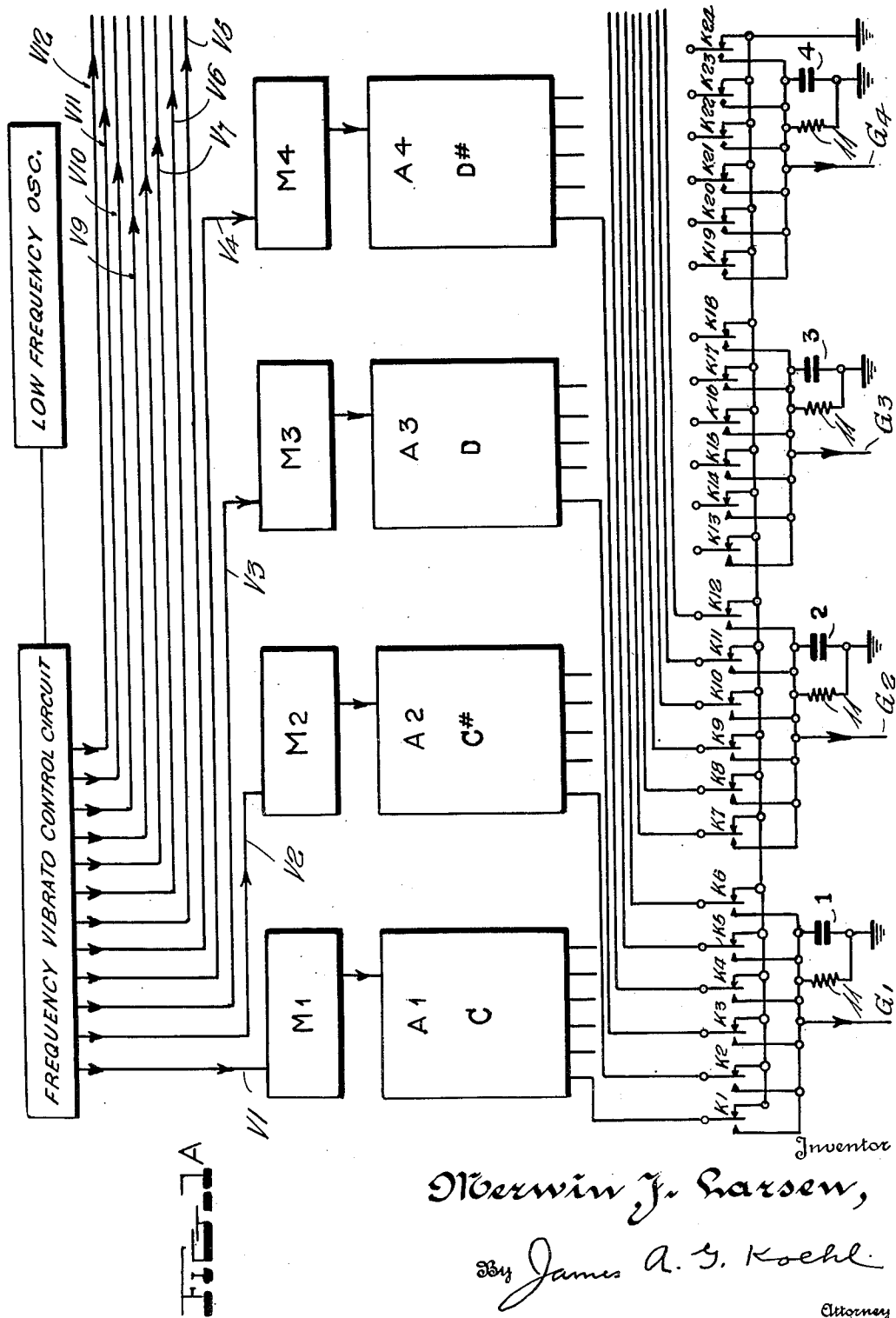
M. J. LARSEN

2,403,090

ELECTRONIC ORGAN

Filed Sept. 19, 1944

9 Sheets-Sheet 2



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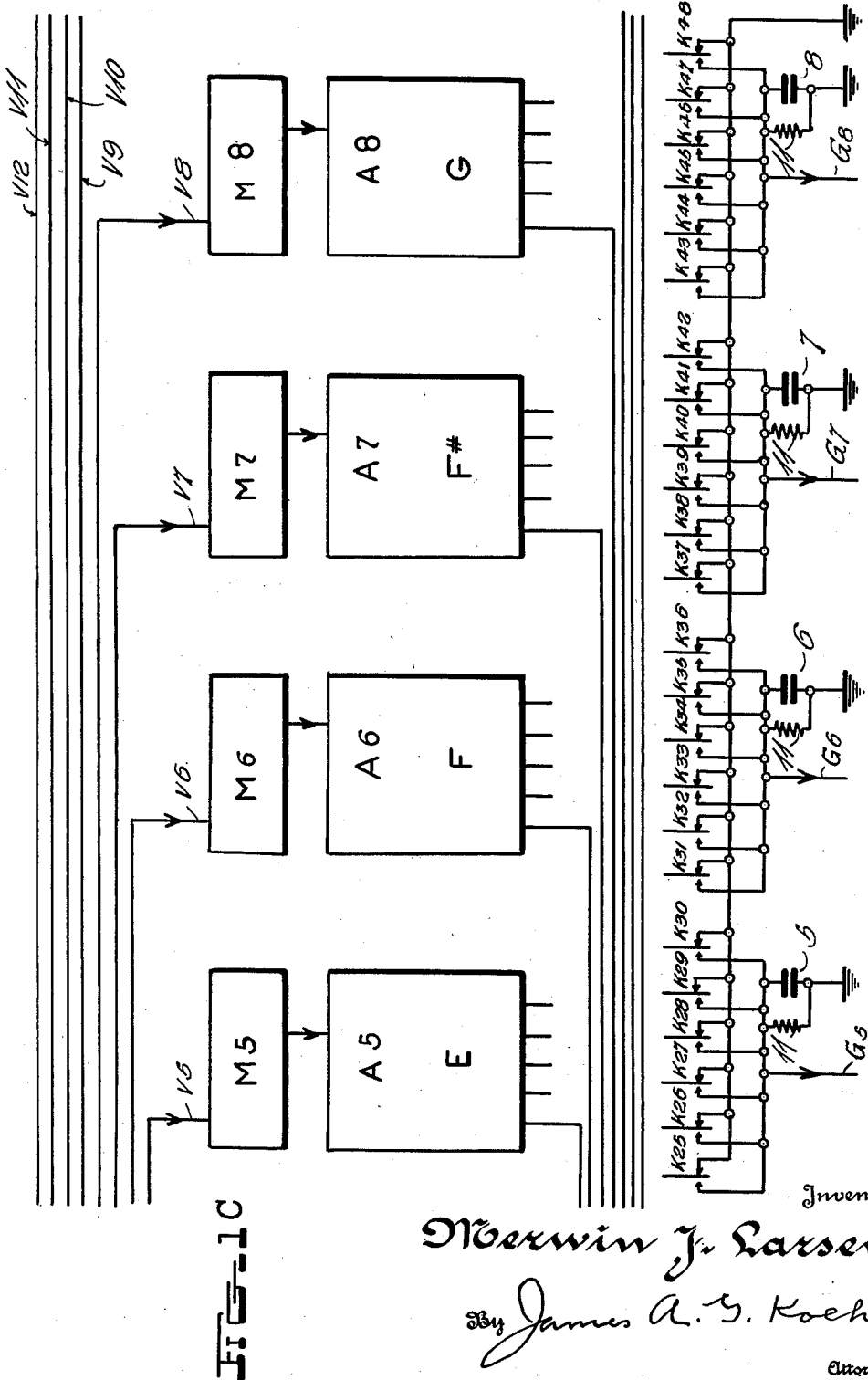
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9 Sheets-Sheet 4



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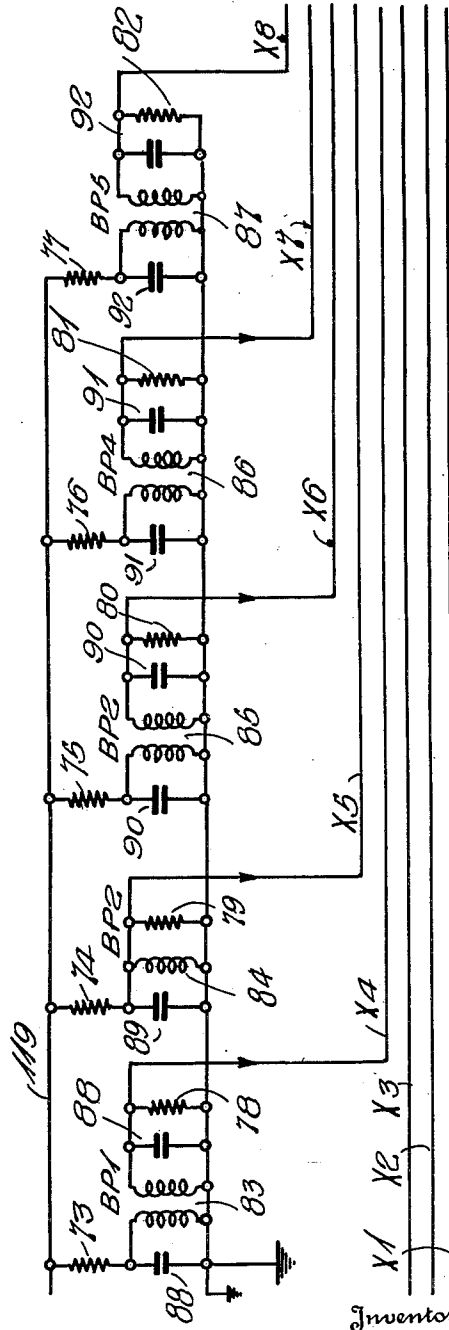
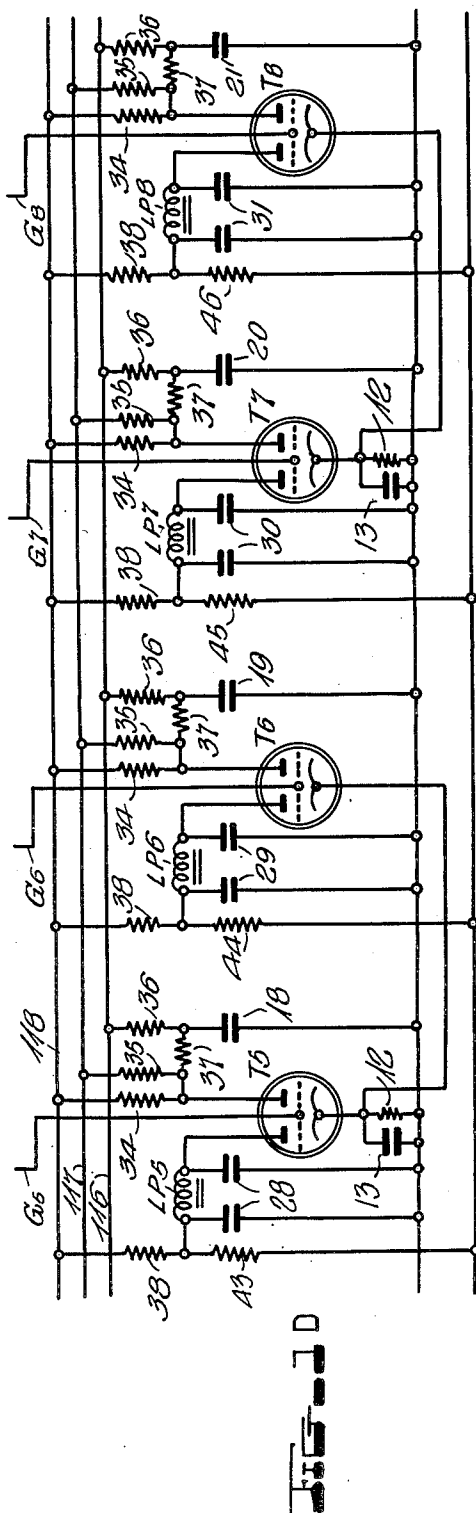
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9 Sheets-Sheet 5



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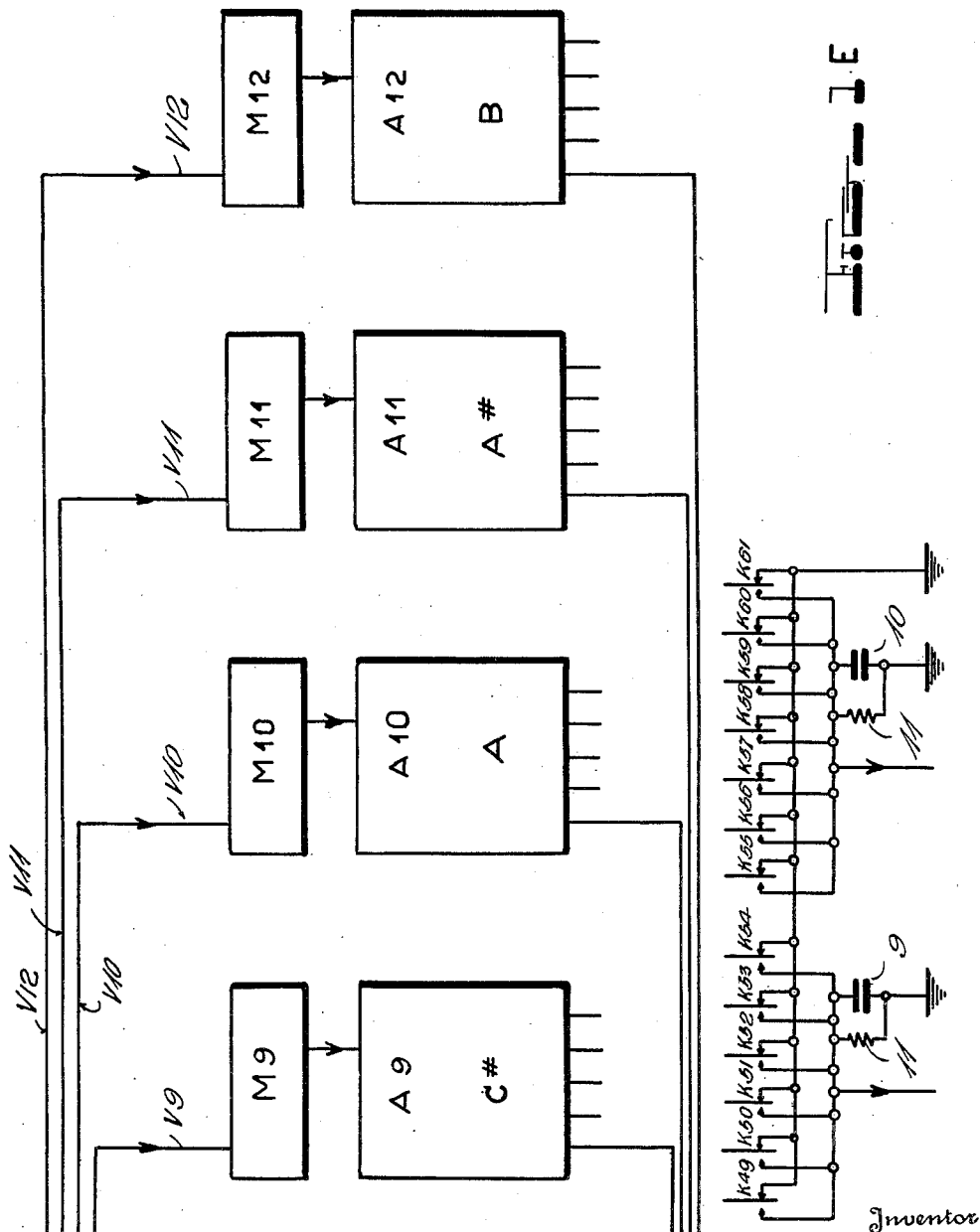
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9 Sheets-Sheet 6



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2,403,090

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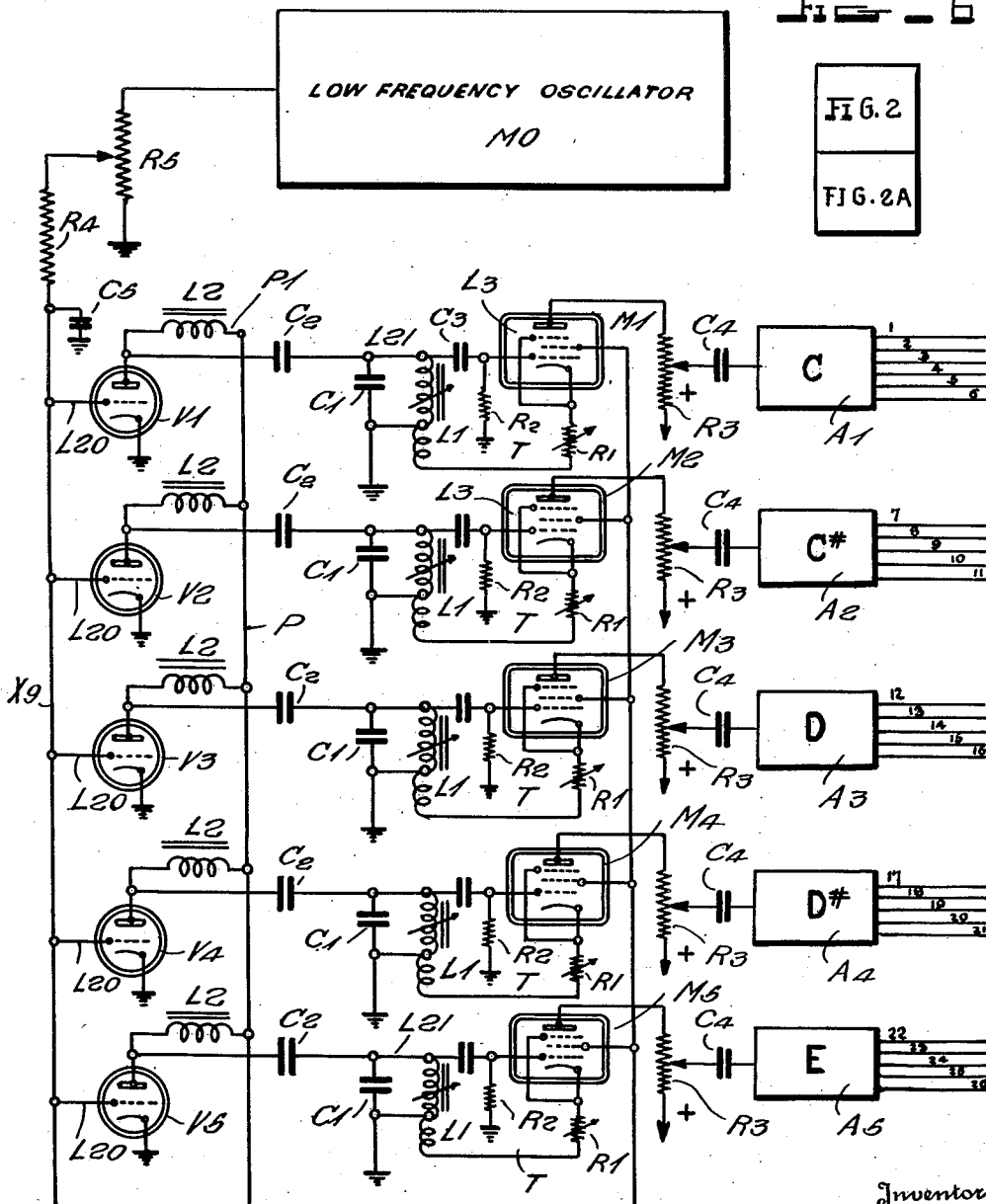
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FIG. 2

FIG. 2A



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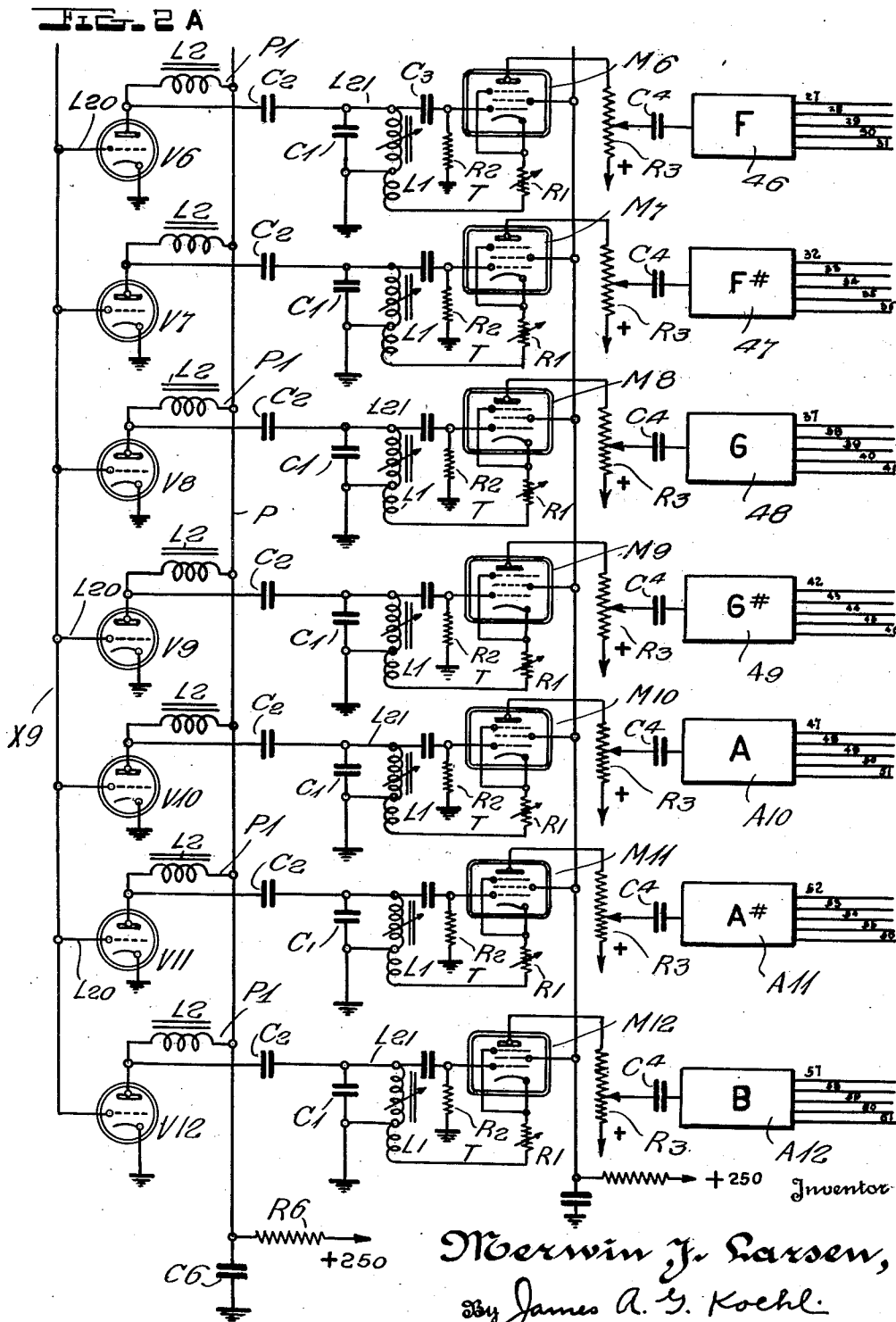
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9 Sheets-Sheet 8



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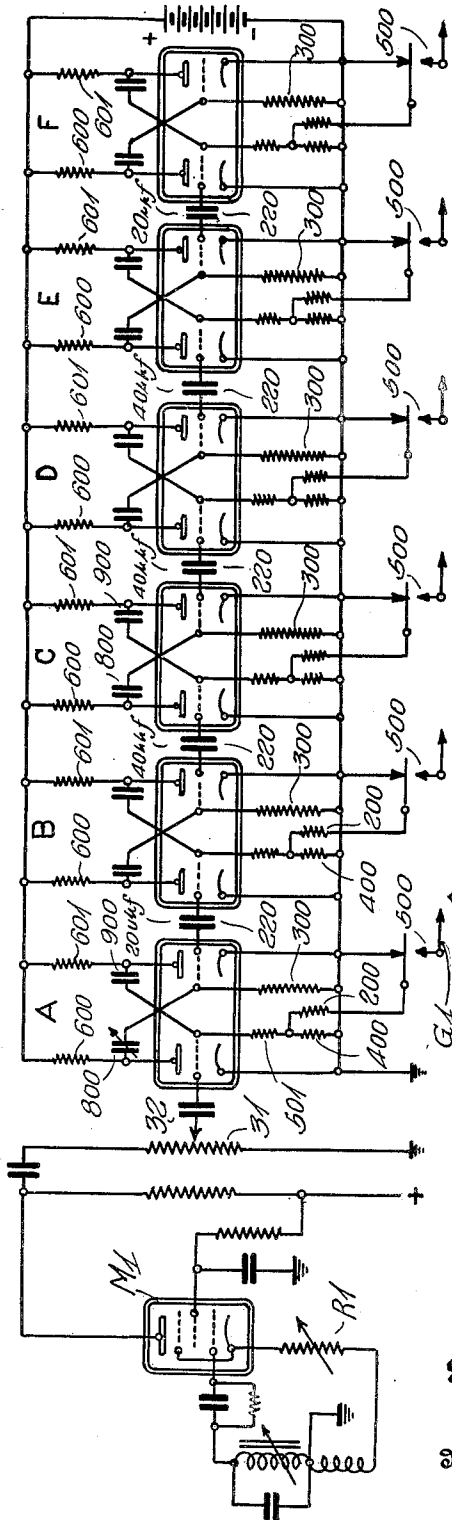
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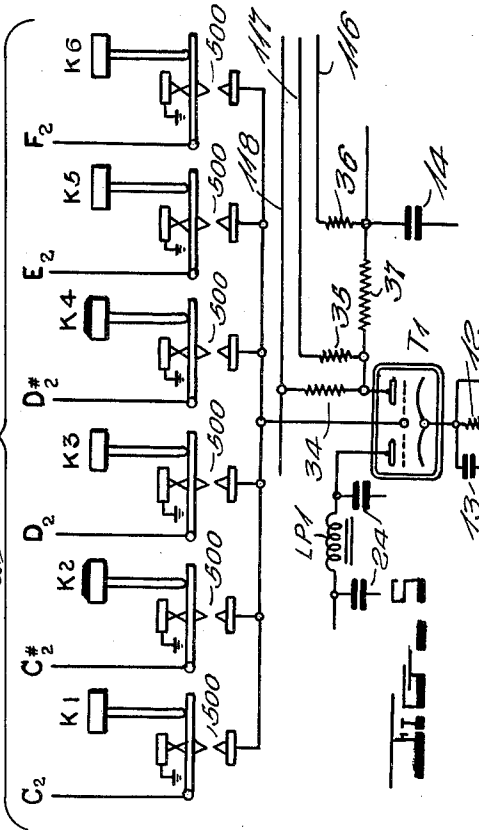
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FIG. 2



1A	1C	1E
1B	1D	1F

FIG. 3



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UNITED STATES PATENT OFFICE

2,403,090

ELECTRONIC ORGAN

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Application September 19, 1944, Serial No. 554,837

38 Claims. (Cl. 84—1.22)

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This invention relates to electronic organs, the essential objects of which, are, as follows:

The provision of improved methods and means for the transmission and reception of audio frequency tone signals in a manner insuring against distortion of said signals.

The provision of improved methods and means for reducing to a minimum cross modulation of the signals and for maintaining a signal level well above the noise level.

The provision of means in the keying circuits employed for isolating signals generated at certain sources from signals generated at other sources and for employing signals from any of said sources in a manner insuring their effective use as intended in my improved method and means by which the quality of a tone can be controlled as desired and with assurance that the harmonics or partials are in the true harmonic relation to each other.

The provision of a harmonic control system for conversion of complex waves of tone frequencies into resultant waves which are characteristic of musical tones of any desired quality.

The provision of a harmonic control system by which a wave rich in harmonics can be converted into a wave in which all but the fundamental or first harmonic are suppressed, thereby enabling production of a simple tone which is comparable to that of the flute.

The provision of a harmonic control system by which a wave rich in harmonics can be simultaneously used for the production of resultant waves varying with respect to each other in their effective harmonic content and one or as many of said resultant waves as desired rendered effective upon an electro-acoustic translating device.

The provision of means in my improved electronic organ for producing additive effects when two or more controlled waves are converted into audible sound for musical expression.

The provision of a harmonic control system which is entirely devoid of complications, is of inexpensive construction dependable in action and characterized by respective means providing formant regions in the audible frequency spectrum, each said regions functioning to provide an output wave different from the output from others of said regions.

The provision of an electric organ which is entirely devoid of moving parts.

The provision of an electronic organ, the given pitch relation of the produced tone frequencies of which will remain invariable and not be subject to changes in temperature or the effect of humidity.

The provision of means for facilitating tuning the instrument.

The provision of a compact and readily portable organ.

The provision of a simplified keying system and

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one which is entirely dependable, yet inexpensive and capable of being readily incorporated in the system.

The provision of an improved mixing system which, in coaction with the aforementioned quality control system, enables production of an almost unlimited number of tone qualities.

The provision of means for amplifying weak tone signals to render same effective in the wave filter circuits herein employed.

The provision of a new and improved method of producing a frequency vibrato effect in the output waves of the tone generators employed herein.

The provision of twelve cascades of multivibrator stages and use thereof in combination with each other and in a new and novel environment for the production of musical results never before attained.

The novel features of my invention are set forth with particularity in the hereto appended claims. The invention, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will be fully understood from the following description of a specific embodiment thereof taken in connection with the accompanying drawings, in which:

Figures 1A to 1F inclusive are respectively sections of the composit network embodying my invention;

Figures 2 and 2A are fragmentary views of the vibrato mechanism employed herein;

Figure 3 is a view of one cascade of multivibrators of the set of twelve similar cascades of multivibrators and control master oscillator therefor;

Figure 4 is a schematic chart illustrating the order of arrangement of Figures 1A to 1F to make a composite view of the organ;

Figure 5 is a schematic view of one of the groups of keying switches and associated playing keys therefor, and

Figure 6 is a schematic chart illustrating the order of arrangement of fragmentary views, Figs. 2 and 2A.

The instrument, the various details and new and novel features of which will hereinafter be described in particular detail, preferably, but not necessarily, employs high vacuum tube oscillators as sources from which complex waveforms of alternating voltages are derived and adapted to be selectively converted into audible sounds for musical expression. A highly dependable frequency dividing system suitable for the purpose of my invention is shown and described in the copending joint application of myself, James A. Oswald and Carl S. Schjonberg, filed September 17, 1943, Ser. No. 502,762. In accordance with the therein disclosed invention, multivibrators connected in cascade function in a highly dependable manner to generate respective output waveforms of alternat-

ing voltages at octavely related tone frequencies, said waveforms being rich in harmonics and therefore adapted to be used to great advantage in combination with new and novel features of my invention.

In carrying out my invention, I employ twelve similar cascades of multivibrator stages, each of which is similar to the single cascade of multivibrators disclosed in the aforementioned copending application. For a keyboard musical instrument employing a scale tuned in equal temperament, there will be a cascade of multivibrator stages respectively generating sensibly identical complex wave-forms of alternating voltages at the tone frequencies of all C notes at octave separation; a cascade of multivibrator stages generating sensibly identical complex waveforms of alternating voltages at the tone frequencies of all C# notes at octave separation; a cascade of multivibrator stages generating sensibly identical complex waveforms of alternating voltages at the tone frequencies of all D notes at octave separation, and so on throughout the gamut of the instrument to and inclusive of a cascade of multivibrators generating sensibly identical complex waveforms of alternating voltages at the tone frequencies of all B notes at octave separation.

Reference herein to alternating voltage sources of the type aforementioned shall not be construed to mean that other well known types of generators may not be substituted therefor without sacrificing any of the advantages of my invention. That is to say, any of the various well known generators may be used, such as generators comprising gas content tubes; electrostatic and electro-magnetic generators employing relative movable electrodes; generators employing photocells and movable waveform scanners, etc. In this connection, reference is made to the following United States patents: Cahill Patent #1,295,691, February 25, 1919; Langer Patent #1,832,402, November 17, 1931; Firestone Re. Patent #21,137, July 4, 1939; and Potter Patent #1,678,872, July 31, 1928. In addition thereto various well known trigger circuits including the well known Eccles-Jordan circuit (reference, Radio Review, 1919, 1, p. 143), sometimes referred to as "flip-flop" circuits and used for frequency dividing a plurality of notes of the tempered scale, may be employed. Such circuits, as distinguished from multivibrators, are completely aperiodic frequency-dividing networks which do not produce independent oscillations, yet, when used as the present disclosure teaches, are suitable for my purpose. In fact, any one of the many other trigger circuits can be employed such as circuits for impulse counting, etc.

The main problem in any instance involving use of oscillators and the various trigger circuits, is that of drift with resultant variations in pitch and the factor of shielding, which latter has heretofore presented difficult problems not easily overcome. I stress herein the numerous advantages flowing from my use of multivibrators in an environment wherein all previously existing disadvantages such as "drift" and shielding are overcome and the pitch relation of tones held constant and made highly dependable over long operating periods of time.

In order that at the outset a simple yet graphic perspective can be readily had of the broad functional characteristics of the various elements, combinations and sub-combinations of elements employed, the generators aforementioned are broadly specified as sources providing waveforms which are rich in harmonics. From these sources,

waveforms at selected pitches are impressed upon an electrical network, thence amplified and converted into audible sounds of any desired timbre.

The instrument herein shown embodies a single keyboard of the conventional 8 foot range wherein $C_2=65.4$ cycles per second and $C_3=2093$ cycles per second. As many keyboards as desired may be provided and the instrument can of course be equipped with a pedal section.

In the aforementioned joint application of myself James A. Oswald and Carl S. Schjonberg, the multivibrator submultiple divider system therein disclosed is preferably controlled by a separate master oscillator, the purpose of which is to insure invariable stability of operation of the system. By reason of the stable master control set forth in said system locking throughout all multivibrator stages is maintained even though the normal plate supply of 150 volts is varied from 20 to 350 volts.

In the present embodiment of my invention I employ twelve cascades of multivibrator stages, each of which is similar to the single cascade of stages disclosed in said copending application except that the cascade developing vibrations for all C notes in a five octave instrument shall have six multivibrator stages, whereas the remaining cascades will each thereof comprise but five such stages. Each cascade is controlled by its own master oscillator.

The C note cascade of multivibrator stages and its master control oscillator is shown at Figure 3, and comprises multivibrator stages A, B, C, D, E and F connected in cascade by electrical components, whereby stage B oscillates at a frequency which is the octave of stage A, stage C operating at a frequency which is the octave of stage B and so on to and inclusive of stage F which operates at a frequency which is the octave of stage E, the master control oscillator being connected to grid circuit of the first stage A.

Each individual cascade of multivibrator stages functions similar to the stages comprising said C note cascade, it being understood that the first stage of each said cascade oscillates at a given frequency, and that the succeeding stages oscillate at frequencies which are submultiples of said given frequency and octavely related to each other. It will suffice to say that for a keyboard, the gamut of which is confined to five octaves the frequency range will be from $C_2=65.4$ cycles per second to $C_3=2093$ cycles per second, the C note cascade comprising six multivibrator stages, whereas each remaining cascade comprises but five multivibrator stages.

For the reason that the herein disclosed system of multivibrators is essentially like the system disclosed in said copending application Ser. No. 502,762, it will be noted on reference to Figure 3 that when playing-key controlled switch 500 associated with stage A is close circuited upon depression of said playing-key, the complex waveform of alternating grid voltage produced by said stage is taken off from a dropping resistance 200, the latter connected between the series resistances 400 and 501. With the circuit thus completed said output waveform of alternating voltage is impressed upon a respective transmission path G1. Each individual multivibrator stage of said cascade functions in a manner similar to that just above stated, whereby upon close circuiting any selected keying switch, the output from a respective stage will be useful in the electrical input network which I will describe presently.

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As the respective multivibrator stages are identical as regards certain of the essential components, it is important that it be noted that the resistances employed are high, in order that the average current drain upon any individual stage is the same and so slight as to insure prolonging the life thereof. All plate resistances **600** and **601** in the plate circuits of each stage are each thereof 1 megohm and therefore symmetrical while the resistances in the grid circuits of each said stage are preferably unsymmetrical. For example, resistance **400** is 10,000 ohms, resistance **501**, 300,000 ohms, resistance **300** 1 megohm, and dropping resistance **200**, 50,000 ohms.

With the above relative values of resistances, experiments show that the output voltage of the fundamental component measured across high resistance **400** is of the order of magnitude of 0.1 volt and is relatively independent of frequency as has been clearly set forth in said copending application 502,762.

In said copending application stress is placed upon use of small coupling capacitances between the respective stages in the cascade of stages therein employed. I stress also the importance of small coupling capacitances in the herein disclosed embodiment of my invention wherein twelve substantially similar cascades are employed. These capacitances are shown in Figure 3 and are used to couple the grid of one triode of a stage to the grid of one triode of the next succeeding stage. The capacitance **220'** between the first and second stages and capacitance **220'** between the fifth and sixth stages are each thereof 20 micro-micro farads, whereas the intermediate capacitances **220** are each thereof 40 micro-micro farads.

To set the multivibrator stages of a cascade of said stages in operation and control such operation capacitances **800** and **900** are employed in the plate to grid circuits of each individual stage, it being noted that capacitance **800** in the first stage is adjustable and that capacitances **900** in each of the succeeding stages are each thereof fixed, the arrangement being such that the frequencies of all succeeding stages will be controlled by simply adjusting capacitance **800** in the circuit of the first stage. Because of the environment in which I employ twelve substantially similar cascades of multivibrators, it follows that but twelve adjustments are necessary to be made when tuning the instrument. That is to say that by the mere tuning of a single octave of notes located any place in the keyboard, all others of the notes in the gamut of the instrument will be automatically correctly tuned.

It is not deemed necessary to dwell further upon the cascades of multivibrators employed as one such cascade has been fully described in said application Ser. No. 502,762, it being borne in mind, however, that for best results, the first stage in the cascades of multivibrators are connected in the control circuits of master oscillators designated M1, M2 . . . through master oscillator M12, a more detailed description of which will follow.

In order that the waveforms generated as aforementioned and which are rich in harmonics can be used for the production of an almost unlimited number of organ and orchestral tones and with additive effects when two or more stops are drawn, my invention is characterized by embodiment therein of a new and novel quality control system. This system comprises a series of low-pass and band-pass filters, the band-pass

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filters providing various formant regions in the audible frequency spectrum, whereby various tone qualities are produced in a manner somewhat analogous to those produced by the human voice. Regarding the physics of sound, it is recognized that in the vocal production of the various qualities the vocal cords act as a generator producing tones rich in harmonics which are modified at will by adjusting the various resonating cavities which are under the control of the singer.

The aforementioned low-pass filters provide means whereby the fundamental components alone of the various waveforms are available for use as desired for the production of tones which are practically, if not wholly, lacking in harmonics.

By a blending of the outputs of the various low-pass and band-pass filters through a simple mixing network a wide range of desirable tone qualities is available and by the means, mechanisms and arrangements of parts herein shown, additive effects are had upon the drawing of two or more stops.

Referring now more particularly to Figures 1A . . . 1F of the drawings wherein twelve sets or cascades of multivibrators are shown in schematic or block diagram, and designated A1 cascade, A2 cascade, A3 cascade to and inclusive of cascade A12, it will suffice to say that cascade A1 generates complex waveforms of alternating voltages at the tone frequencies of all C notes; that cascade A2 generates complex waveforms of alternating voltages at the tone frequencies of all C# notes and that A3 cascade generates complex alternating voltages at the tone frequencies of all D notes. Thus, for a keyboard whose gamut is confined to sixty-one playing keys there is a multivibrator for each individual playing key. The divider circuits herein employed insure generation by each cascade of alternating voltages at octave separation and as there are twelve cascades in the set illustrated, it follows that the frequencies generated by the respective cascades are in accordance with the chromatic octave for an instrument tuned to the even tempered musical scale.

In the present example of my invention, the keys are grouped into 10 divisions of 6 notes each, save for the last group which includes 7 notes. The particular grouping arrangement being in accordance with the following chart:

Key groupings

	Note number	Note letter	Tempered scale theoretical frequencies
Group 1.....	1	C ₂	65.4- 87.3~
	2	C# ₂	
	3	D ₂	
	4	D# ₂	
	5	E ₂	
	6	F ₂	
Group 2.....	7	F# ₂	92.5-123.5~
	8	G ₂	
	9	G# ₂	
	10	A ₂	
	11	A# ₂	
	12	B ₂	
Group 3.....	13	C ₃	131- 175~
	14	C# ₃	
	15	D ₃	
	16	D# ₃	
	17	E ₃	
	18	F ₃	
Group 4.....	19	F# ₃	185- 247~
	20	G ₃	
	21	G# ₃	
	22	A ₃	
	23	A# ₃	
	24	B ₃	

Key groupings—Continued

	Note number	Note letter	Tempered scale theoretical frequencies
Group 5.....	25	C	262- 349~
	26	C#	
	27	D	
	28	D#	
	29	E	
Group 6.....	30	F	370- 494~
	31	F#	
	32	G	
	33	G#	
	34	A	
Group 7.....	35	A#	523- 698~
	36	B	
	37	C ¹	
	38	C# ¹	
	39	D ¹	
Group 8.....	40	D# ¹	740- 980~
	41	E ¹	
	42	F ¹	
	43	F# ¹	
	44	G ¹	
Group 9.....	45	G# ¹	1046- 1397~
	46	A ¹	
	47	A# ¹	
	48	B ¹	
	49	C ²	
Group 10.....	50	C# ²	1480- 2093~
	51	D ²	
	52	D# ²	
	53	E ²	
	54	F ²	
	55	F# ²	
	56	G ²	
	57	G# ²	
	58	A ²	
	59	A# ²	
	60	B ²	
	61	C ²	

The specific grouping of the keys just referred to is not to be construed as limiting the invention in this respect, but, and in the instance herein disclosed, is recommended for reasons which will appear presently. The outputs of each key group are terminated in capacitors 1, 2, 3 . . . 10, inclusive, and resistances 11, the capacitances being of such values that their reactances are substantially the same at the approximate mid-frequency range of their respective groups. This reactance must be considerably lower in value than that of the individual generator output impedances in order to prevent "robbing." In general, the resistance 11 has a value somewhat higher than that of the aforementioned reactance of its shunting capacitance and may be considered as a check to reduce any lower-frequency stray voltages which might arise. The output of each key group is impressed on the grids of tubes T1, T2 . . . T10 respectively. These tubes may be twin triodes as indicated or separate triodes or pentodes. The function of these tubes is to divide and isolate the groups from each other and also to provide separate isolated output channels for a purpose presently to appear. For example, the grids of T1 are in common, and the cathodes are in common, whereas one plate of one triode is connected to a low-pass filter circuit to activate the filter LP1. The plate of the other triode passes through decoupling resistance 35 to a common lead 117 and also through resistances 37 which, in connection with capacitance 14, suppresses the higher harmonics of the waveforms in the group concerned to a lower level. The output across capacitance 14 passes through decoupling resistance 36 to a common lead 116. Thus, it follows that output from T1 may pass through a plurality of separate output paths. Similar provision is made for the other tubes T2, T3 . . . T10. The filtering capacitances 14, 15, 16 . . . 23, however, differ in value in order to provide essentially the same reactance at the mid-fre-

quency of their corresponding key groups. The magnitudes of these reactances, for example, are substantially the same as the magnitudes of the resistances 37. It is understood that all vacuum tubes employed herein, such as tubes T1, T2 . . . T10, will be connected in my improved electrical network according to common radio practice, i. e. each said tube will be received in a conventional socket and the latter connected with its respective circuits.

In the combined Figures 1B, 1D and 1F, wherein ten high vacuum tube isolators T1, T2, etc., are shown for as many individual groups G1, G2, etc., of playing-key switches, the common cathodes of the odd numbered twin triode tubes are connected to ground by resistive capacitative circuits, including resistance 12 in series between ground and said common cathodes and capacitances 13 in shunt between said resistances and ground, the even numbered tubes being coupled to said resistances at the terminals thereof which connect with said cathodes.

The output from common lead 116 is amplified by a conventional resistance-coupled stage T12, the output of which is fed to conductive lead X2 of the mixing network M. The output of common lead 117, carries a waveform rich in harmonics from resistance 35 in the second output branch from the plate of the right hand triode of stage T1, and leads to a conventional amplifier stage T13, the output of which is divided, part going to the mixer through lead X3 and the other part going to an amplifier stage T14, which supplies a group of band-pass filters and thence to mixing network M.

These band-pass filters are designated BP1, BP2 . . . BP5 and, as shown, they are coupled to common input lead 119 through decoupling resistances 73, 74 . . . 77. Each of said filters has a separate output lead to the mixer, which leads are designated X4, X5 . . . X8. The characteristics of these band-pass filters will be discussed hereinafter.

The outputs of all of the aforementioned low-pass filters pass to a common lead 118 through respective decoupling resistances 39, 40 . . . 43, inclusive. The common lead 118 carries the substantially sinusoidal waves of frequencies corresponding to the fundamental components of the respective notes in the instrument's gamut. The output of lead 118 is amplified through the conventional amplifier stage T11, the output of which passes to the mixing network via a lead X1.

The function of the mixing network is to provide a means of selecting any number of outputs from the various leads X1, X2 . . . X8 at predetermined amplitudes. This is accomplished by means of decoupling resistances 93, 94 . . . 112 which connect either singly or in groups to simple "stop" switches designated S1, S2 . . . S11. When the switches are "on," the main amplifier 120 activates the speaker 121. When any stop switch is in the off position, the contact lever connected to its associated resistance group 93 . . . 112 is grounded through common lead 113 in order to prevent "cross talk."

The amplifier input resistance 114 is necessarily much lower than any of the decoupling resistances 93, 94 . . . 112, in order to prevent "robbing" amongst the stops. Likewise the decoupling resistances just mentioned should be higher than the output impedances associated with said common leads X1, X2 . . . X8, although the relative proportioning in this case will de-

pend upon the particular choice of qualities set up for the whole system.

Low-pass filter LP1 is designed to start attenuating at F₂ which has a frequency of 87.3 cycles per second. By this means there is no component having a frequency between 87.3 cycles and 130.8 cycles which ever enters the filter, thus providing a wide margin allowing for attenuation. The lowest frequency mentioned outside of the fundamental note range associated with this group, namely 130.8 cycles, corresponds to the frequency of the second harmonic produced by the lowest note C₂ in this particular group. If, for example, the key groups should comprise 12 notes each, the second harmonic of the highest note in that group would be attenuated adequately with a simple low-pass filter, but the second harmonic of the lowest note in that particular group would be attenuated but slightly as it is so close to the frequency of the fundamental of the highest note in said group. It therefore follows that with 12 or more notes in a group a change in tone quality takes place from one end to the other within said group. By means of the aforementioned lesser number, say 6 notes to a group, the difficulties aforementioned are not encountered and a simple low-pass filter can be employed that will function in a highly satisfactory manner.

Use of the term or expression "simple" employed herein and applied to the low-pass filters in the disclosed environment of said filters shall be construed to mean a filter which need not have a sharp cut-off or a specially designed terminating network, such, for example, as would be required for an *m*-derived filter or a filter employing several sections.

The components separately listed herein and associated with the low-pass filters were determined largely experimentally and under conditions of operation similar to those employed in the circuits shown herein. It is of course understood that the modus-operandi of all others of the low-pass filters herein employed is substantially the same as that of filter LP1 just above explained.

The purpose of the band-pass filters is to provide a series of formant regions of a number and spacing along the frequency spectrum adequate to provide a choice of tone qualities when used by themselves and/or with other sources associated with the mixing network. In the present example of my invention, five band-pass filters are employed. The particular band-pass filters employed herein have a rather high coefficient of coupling of between four tenths and five tenths which permits a relatively wide band of frequencies to pass through. The coils 83, 85, 86 and 87 are air-core, wound coaxially, each coil having an inductance of approximately 300 millihenries. The capacitances 88, 90, 91 and 92 are adjusted experimentally to provide the desired band-pass region. For example, the mid-frequencies of the bands employed are 500 cycles for band-pass filter BP—1; 800 cycles for band-pass filter BP—3; 1500 cycles for band-pass filter BP—4 and 2200 cycles for band-pass filter BP—5.

Each of these would reinforce predominantly over a range extending approximately half an octave, although the attenuation outside the band is not sharp. One of the filters herein called a band-pass filter, namely, filter BP—2 is simply a loaded resonant circuit having a more narrow pass region which resonates at approximately 1400 cycles. The terminating resistances 78,

79 . . . 82 determine to a large extent the sharpness or "Q" of the filter. These outputs pass to the aforementioned leads X4, X5 . . . X8 which supply the mixing network. It is understood that within the scope of the hereto appended claims, various changes, modifications and departures can be made, such, for example, greater or less number of band-pass filters, different choices of band-pass regions; different widths of said regions and different sharpness of tapering outside said regions.

The waveform of any single note which appears on the output of the common lead 116 is essentially the same in its harmonic constitution irrespective of the note played. Because of the aforementioned selective filtering action of the resistances 37 and capacitances 14, 15 . . . 23, this waveform is predominantly the fundamental together with a large series of rapidly tapering higher partials. This waveform appears amplified on lead X2 which supplies the mixing network. It should be noted here that successive filtering by resistance-capacitance networks would require a very large array of sections before a more flute-like tone quality would be possible which would compare with the low-pass filters. This follows because, in capacitance-resistance networks higher partials are suppressed, yet are not completely obliterated as with the low-pass filters just described. The waveform of any tone on the common lead 117, on the other hand, is richer in harmonic output as the only integrating action employed is that of capacitances 1, 2 . . . 10 which are associated with their respective key groups G1, G2 . . . G10. If the individual tone generator output waveform is rich in harmonics as the case in the generator disclosed in said copending application of myself, James A. Oswald and Carl S. Schjonberg, Ser. No. 502,762 filed September 17, 1943, then the waveforms appearing on lead 117 is still moderately rich in its harmonic composition. This waveform appears amplified on lead X3 which connects to the mixing network and is also the same waveform which appears further amplified on the common lead 119 which supplies the aforementioned band-pass filters.

Referring now to the vibrato control circuit shown in Figs. 2 and 2A use is made of master oscillators M1, M2 . . . M12 which are conventional electron-coupled oscillators with the exception that provision is made to vary the frequency of said master oscillators over an adjustable extent and rate. In practice, I have found vacuum tubes made by Radio Corporation of America and known as type 1A7 to be entirely suitable for my purpose when connected as herein shown and described. There is one of said master oscillators for each individual cascade of multivibrators, the output wave from which is impressed on the control grid of the first stage of said cascade.

In Figures 2 and 2A there is shown a common lead P connected by a resistance R6 to a plate supply source, not shown, said lead having a large capacitance C6 connected in shunt therewith. Small chokes L2 in the branch circuits P1 of common lead P are connected in the plate circuits of respective control tubes V1, V2, etc. At X9 is a common lead, the branch circuits L20 of which connect in the grid circuits of said respective control tubes.

At MO is a low frequency oscillator, the output of which has a potentiometer R5 in series with a dropping resistance R4 at the input ter-

minal of said common lead X9, a capacitance C5 being connected in shunt with said lead, as shown.

The master oscillator tubes M1, M2, etc., for the first stages of the respective cascades, A1, A2, etc., of the multivibrator waveform generators are each thereof connected in a "tank" circuit T which is individual thereto and includes a lead L21 connecting the plate of a respective control tube to the control grid of an associated master oscillator. In series with said lead are capacitances C2 and C3. A capacitance C1 is connected in shunt with said tank circuit and has a terminal point of connection between capacitances C2 and C3, the opposite terminal of said capacitance connecting with a variable inductance L1 between the field coils thereof. A terminal of one coil of said inductance connects with said lead L21 between capacitances C2 and C3, and, as illustrated, a terminal of the other coil of said inductance is connected in the cathode circuit of a respective master oscillator by an adjustable feedback resistance R1 and with the suppression grid of said master oscillator by a lead L3.

The low frequency oscillator MO may be any of several types such as one of the simpler R.-C. types, provided the output waveform is substantially sinusoidal. See, for example the publication entitled UHF Techniques by Brainerd, page 181, also any circuit shown and described at page 193 of said publication. The rate is adjusted to approximately 6 cycles per second although manual control of the vibrator rate may in some instances be controlled as desired. The extent of the frequency sweep is under control by adjustment of the aforementioned potentiometer R5 in the output of said low frequency oscillator.

Resistance R4 is of the order of magnitude of 200,000 ohms and prevents the grids of the control tubes from swinging appreciably above their respective cathodes and at the same time, avoids possible overloading of the low frequency oscillator during its positive swing. Capacitance C5 which is connected in shunt with lead X9 is of the order of magnitude of 0.1 microfarad and functions as a filter to reduce the higher harmonics which tend to be produced during the positive portion of the cycle when the grids of said control tubes rise slightly above their respective cathodes, at which time, the plate resistance of said tubes are at their lowest value as is true also of the frequencies of the master oscillators. Both cathode and grid bias are eliminated by passing the plate supply to the control tubes through resistance R5 in the main plate supply lead P which is shunted by a large capacitance C6, say 40 microfarads. No change in pitch is in evidence whether the vibrato is "on" or "off." The vibrato is turned off by grounding the output of the low-frequency oscillator, preferably at the oscillator side of the dropping resistance R4 either by means of a switch or by adjusting potentiometer R5.

The small chokes L2 insure a much greater range in dynamic plate resistance than is possible with the use of resistances. This is due to the fact that a much higher plate voltage is retained, which, in turn, permits a lower plate resistance during the positive swing of the grid voltage cycle.

The design of the master oscillator with its frequency control circuit depends upon the maximum extent desired for the frequency swing. In a frequency vibrato to be used for musical pur-

poses the extent of the frequency sweep, likely, would rarely exceed 5 per cent which is a little less than a semi-tone. This would correspond to a change of approximately 10 per cent in either the inductance or the capacitance (L1 or C1) of the tank circuit as the frequency is inversely proportional to the square root of the product of the inductance and the capacitance. It has been found that if C2 is on the order of 0.1 of C1, an adequate maximum swing can be obtained, somewhat less than 5 per cent, provided a tube is selected and operated so that its dynamic plate resistance can become as low in magnitude as that of the reactance of C2 at the frequency of the master oscillator concerned.

In selecting the proper values, the choke L2 should have a reactance several times that of C2 at the oscillator frequency. For a given tube, V1, the optimum value of C2 is such that its reactance equals the lowest attainable value of the plate resistance of the tube. (Optimum is used in the sense that the greatest frequency change is possible with this value.) Should this optimum value of C2 be too high a percentage of C1 the tube selected will more than handle the maximum desired frequency swing and consequently C2 can be reduced. If, on the other hand, the optimum value of C2 is too small a percentage of C1, either the oscillator must be redesigned using a smaller C1 and a larger inductance, or a tube having a lower plate resistance must be used.

Assume as a design example that a 6SC7 or (7F7) triode section is to be considered as the control tube along with a master oscillator operating at a frequency of 3000 cycles per second. Without drawing appreciable grid current, at zero bias, the lowest attainable plate resistance is about 40,000 ohms with a plate voltage of 150 volts. In order, then, for the reactance of C2 to equal 40,000 ohms C2 would be about 0.0013 microfarad. This means that C1 should be about ten times as much or about 0.013 microfarad. The oscillator inductance L1 can be designed now to provide the proper frequency. In the plate lead of the control tube for choke L2 a "midget" 10-henry choke would be adequate as it would have a reactance of nearly 200,000 ohms at the oscillator frequency. The input on the grid of V1 should be great enough to swing the grid from zero bias to or near to the cut-off bias, for maximum vibrato, and less swing as desired.

The values given in the example above are intended to point out the approximate design only. In construction it is not necessary to design closely. To come "somewhere near" the design value usually is quite satisfactory.

For locking the multivibrators it has been found that there is an optimum potential which will provide best locking. The optimum potential is obtained readily by adjustment of the potentiometers R3 to which the multivibrators are connected through capacitances C4.

A few general remarks can be made about the system as a whole. In order to reduce cross modulation to a minimum it is necessary that the various signal levels be held low as possible. Yet amplification is necessary by means of stages T11, T12, T13 and T14 to compensate for the subsequent losses in the mixing system. In other words, a balance is sought in the system which will maintain the signal level well above noise level, but not high enough to produce objectionable cross modulation.

Elsewhere in the description the tubes T1, T2, ... T10 were referred to as having an iso-

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lating function. Suppose, for example, the low-pass filters were not isolated and grouped in some such manner as explained but that the inputs were connected to a common lead via decoupling resistances. With this erroneous connecting scheme the higher harmonics of a lower note would be present in some higher note filter and the system would become ineffective. A similar argument holds for the resistance capacitance filtering outputs which outputs connect to lead 116.

On the wiring system certain simplifications result in that shielded wires are unnecessary between the generating units and the keys because the leads are grounded when the keys are in the "off" position and thus no crosstalk can occur from the unoperated generators.

Tuning of the instrument is accomplished through the master oscillators M1, M2 . . . M12 the frequencies of which are adjusted by moving a powdered iron core within the inductance coils L1, or by other means, such as, for example, capacitance trimmers. Inasmuch as each octavely locked unit C, C# . . . B is locked in turn by its respective master oscillator M1, M2 . . . M12, it follows that only twelve tuning adjustments are necessary in order to tune the instrument in a minimum of time.

I stress the new and novel features of the mixer M herein employed and point particularly to its simplicity of construction and the fact that the switches S1, S2, etc., have their contactors M1 at ground potential when the switches are open circuited, thereby preventing interaction between said switches. These switches are of the single pole, double throw type, the pole M2 of each of which connecting with one or more continuations of the conductors X1, X2, etc., by the aforementioned resistances 93, 94, 95, etc. In this manner, the magnitude of signals from the quality control system is predetermined, such, for example, that the waveform impressed upon the input circuit of the amplifier when close circuiting stop switch S4 is a mixture of tone signals from band-pass filter leads X4, X7 and X8 and amplifier T11, the latter connected in the common output 118 from the low-pass filters LP1, LP2, etc. It follows from this that any tone signal of predetermined complex waveform can have mixed therewith a tone signal of sinusoidal waveform and at any amplitude determined by the proper value of resistance through which said signal passes.

Similarly the amplitudes of any complex waveform transmitted to the mixer is controlled by the value of the resistance in its transmission path.

Stops S2 and S3 are shown connected by resistances 94 and 95 to the same transmission conductor, namely, conductor X1 from the common output 118 of the low-pass filters T1, T2, etc. As the output from these filters is sinusoidal, the quality resulting from its conversion into audible sound is characteristic of the flute. As the resistances 94 and 95 are of different predetermined relative values, stops S2 and S3 are indicative of the same quality but at respectively different amplitudes.

By the means herein fully shown and described the quality of most any musical instrument can be very closely simulated. There can be any desired admixtures of waveforms when two or more stops are drawn at any instant and these admixtures will be additive, the same as is characteristic of the pipe organ.

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The above named features in combination with the aforementioned means for preventing interaction between the groups of keying means, to which may be added the feature which consists in providing an amplifier resistance 114 which is much lower than any of the decoupling resistances 93, 94, etc., and the feature which consists in decoupling resistances 93, 94, etc., which are higher than the output impedances associated with conductors X1, X2, etc., insure more faithful reproduction of musical tones than heretofore has been possible with devices of the prior art. While these niceties may seem more or less trivial, they are, in fact, of major importance.

By reason of the low voltage generated by the above mentioned multivibrators, it is highly important that there shall be no interaction between the several groups of switches which control transmission of the respective voltages to the input network of the system and that said voltages be enlarged or suitably amplified and not modulated when distributed to their respective wave filters. These features have been previously explained and it need only be said that by reason thereof and the fact that the keying switches are grouped as aforesaid, modulation of the output signals is prevented. In the absence of these features modulation which might possibly be introduced, would to some appreciable extent defeat certain of the broad objects of my invention. As it is, the output signals from each group of keying switches comprise given fundamentals only and harmonics forming the harmonic series of said fundamentals. In the instant embodiment of my invention, a generated wave of predetermined fundamental frequency and its associated true harmonics are repeated in respective circuits as waves differing from each other and from said generated wave. To the end that the generated wave shall not be modulated before entering the input network of the effective filtering system, I have resorted to the various electrical components now described in complete detail.

The term "consisting" used in certain of the hereto appended claims shall be defined to mean that one output wave from each keying group of the keyboard of the instrument is substantially devoid of harmonics forming the upper series of harmonics of said wave.

The term "comprising" used in certain of the hereto appended claims shall be considered in the inclusive sense of the term and has reference to other output waves from each keying group of the keyboard, such that these waves include both the fundamental frequencies of the generated waves and certain components of the harmonic series of said fundamentals.

I emphasize those novel features of my invention which include capacitative keying groups and associated waveform generators for said groups wherein the reactances of said groups are substantially the same at the approximate midfrequency range, and are considerably lower in value than that of the individual generator output impedances, thereby preventing "robbing" when simultaneously drawing upon a plurality of generators. These features, plus the fact that the outputs from respective keying groups are isolated from each other to prevent interaction therebetween insure transmission to the input network of the system of waveforms which are exactly the same as the waveforms produced by said generators and impressed upon said input

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network at any instant. In the absence of the above features, the system as a whole would be lacking in that dependability necessary to insure that the fundamentals of the repeated waves shall always be the same as the generated waves impressed upon the input network at any instant. By the same token the components forming the harmonic series of any individual generated wave will be the same when taken into the input network, whereas and according to the choice of the player, the repeated wave will be different from the generated wave in its harmonic construction above the first harmonic of fundamental frequency.

To the various features just above pointed to 15 there is the added feature which consists in providing resistance 114 in the input to the power amplifier 120, the same being low relative to the decoupling resistances 93, 94 . . . 112 in the aforementioned mixing system but high relative 20 to the output impedances of leads X1, X2 . . . X3.

Bearing in mind the functional characterizing features of my improved quality control system, it manifestly follows that the above named new and novel features of my invention contribute thereto to the end that by their coaction with each other greatly improved musical results are possible.

The electrical values of the elements as numbered and lettered on the drawings and several circuits and networks and preferred types of vacuum tubes employed are approximately, as follows:

Condensers

1. 1 mfd.
2. .07 mfd.
3. .05 mfd.
4. .035 mfd.
5. .025 mfd.
6. .017 mfd.
7. .012 mfd.
8. .008 mfd.
9. .006 mfd.
10. .004 mfd.
13. 50 mfd.
14. .005 mfd.
15. .004 mfd.
16. .003 mfd.
17. .002 mfd.
18. .0015 mfd.
19. .001 mfd.
20. .0006 mfd.
21. .0004 mfd.
22. .0003 mfd.
23. .0002 mfd.
24. .17 mfd.
25. .12 mfd.
26. .086 mfd.
27. .061 mfd.
28. .043 mfd.
29. .031 mfd.
30. .022 mfd.
31. .015 mfd.
32. .011 mfd.
33. .008 mfd.
- 40-53. 1 mfd.
- 55-57. 10 mfd.
58. .25 mfd.
88. .15 mfd.
89. .05 mfd.
90. .09 mfd.
91. .05 mfd.
92. .025 mfd.
92. .002 mfd.
- C3. .002 mfd.
- C4. .250 mfd.
- C5. .1 mfd.
- C6. 40 mfd.

Resistors

11. 33,000 ohms
12. 100 ohms
34. 125,000 ohms
35. 500,000 ohms
36. 1 megohm
37. 500,000 ohms
38. 10,000 ohms
39-48. 100,000 ohms
60-62. 125,000 ohms
63-66. 100,000 ohms
67. 50,000 ohms
68-70. 900 ohms
71. 1,100 ohms
73-77. 100,000 ohms
78-82. 25,000 ohms
114. 5,000 ohms
200. 50,000 ohms.
300. 1 megohm
400. 10,000 ohms
501. 300,000 ohms
600. 1 megohm
601. 1 megohm
R1. 1,000 ohms
R2. 500,000 ohms
R3. 25,000 ohms
R4. 200,000 ohms
R5. 500,000 ohms
R6. 50,000 ohms

Coils

- | | | |
|----------------|-------------------------|----------------|
| 49-53. .1 mfd. | 83-87. Band pass coils. | Each section |
| 55-57. 10 mfd. | 300 millihenries | Coupling coef- |
| 58. .25 mfd. | | ficient 0.4. |
| 59. .15 mfd. | LP1. 34.4 henries | |
| 59. .05 mfd. | LP2. 27.4 henries | |
| 90. .09 mfd. | LP3. 17.2 henries | |
| 91. .05 mfd. | LP4. 12.2 henries | |
| 92. .025 mfd. | LP5. 8.6 henries | |
| C2. .002 mfd. | LP6. 6.1 henries. | |
| C3. .002 mfd. | LP7. 4.3 henries. | |
| C4. 250 mfd. | LP8. 3.05 henries. | |
| C5. .1 mfd. | LP9. 2.16 henries | |
| C6. 40 mfd. | LP10. 1.52 henries. | |
| | L2. 10 henries. | |

Tubes

- T. 7A7
T1-T13. 68C7
V1-V12. 68C7
T14. 6J5

Wherever in the hereto appended claims, reference is made to capacitative output leads, i. e. leads, G1, G2 . . . G10, this shall be construed to include the resistances R1 and their shunting capacitances C1, C2 . . . C10 in the respective switch

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groups. The term "lead" shall include any wire continuations thereof which connect with switches **K1, K2 . . . K61** in the respective switch groups as will be readily understood on reference to Figures 1A, 1C and 1E.

The term "selecting" as employed in the annexed claims, shall be taken to mean the keying switches **K1, K2 . . . K61** arranged as described and connected to preassigned generators. The term "separating" employed in the claims, shall mean switches of a common group of switches, serving to provide a group of outputs in the pitch relation to sequentially related notes associated with different playing-keys of the instrument. The term "isolating" shall be taken to mean the high vacuum tube devices **T1, T2 . . . T10** or other well known electron discharge devices or their functional equivalent, each said isolating device being individual to a respective switch group.

What I claim as my invention is:

1. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes of the chromatic scale, a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group connected together by a common output lead; means connecting the output leads of said groups of switches into respective filter systems through separate paths, said filter systems producing waves differing from waves in said output leads only in their harmonic composition above the fundamental frequency components thereof; and a mixer interconnecting said filter systems with said translating device.

2. The combination set forth in claim 1, in which one of said filter systems comprises a filter for each separate switch group for suppressing essentially all harmonic components of the fundamental frequencies of waves in the output lead of said group and is connected to one of said paths for conduction of resultant output waves thereto.

3. The combination set forth in claim 1, in which one of said filter systems comprises a filter for each separate switch group for suppressing essentially all harmonic components of the fundamental frequencies of waves in the output lead of said group and is connected to one of said paths and provided with a decoupling resistance for passage therethrough of all said waves, the harmonic frequency components of which have been suppressed, as aforesaid.

4. The combination set forth in claim 1, in which means are embodied in the output leads of the respective switch groups for preventing interaction therebetween.

5. The combination set forth in claim 1, in which means are embodied in said mixer for preventing "robbing" amongst output waves during conduction thereof from said mixer.

6. The combination set forth in claim 1, in which means are embodied in the output leads of the respective switch groups for preventing interaction therebetween and wherein means are embodied in said mixer for preventing "robbing" amongst waves simultaneously conducted to the translating device from said paths.

7. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than a single octave of notes of the chromatic scale, a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common capacitative output lead; means connecting the output leads of said groups of switches into respective filter systems producing output waves differing from waves in said output leads only in their harmonic composition above the fundamental frequency components thereof; and a mixer interconnecting the filter systems with said translating device.

8. The combination set forth in claim 7, in which the capacitances in the output leads of said switch groups are of such relative values that their reactances are substantially the same at the approximate mid-frequency range of their respective groups and lower than that of the individual generator output impedances.

9. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than a single octave of notes of the chromatic scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device; switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the frequencies of notes associated with sequentially related playing-keys of said keyboard; the switches of each separate group of switches connected together by a common output lead having a capacitance, and a resistance connecting said capacitance in shunt in said lead; means connecting the output leads of said groups of switches into respective filter systems producing output waves differing from waves in said output leads only in their harmonic composition above the fundamental frequency components thereof; and a mixer interconnecting the filter systems with said translating device.

10. The combination set forth in claim 9, in which the capacitances in the output leads of said switch groups are of such relative values that their reactances are substantially the same at the approximate mid-frequency range of their respective groups and lower than that of the individual generator impedances and the resistances are higher than said capacitances.

11. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes of the chromatic scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys, the switches of each separate group of switches connected together by a common output lead; means including a wave amplifying circuit in which said leads are connected for amplifying output waves therefrom; a filter system producing output waves differing from the waves in said leads only in

their harmonic composition above the fundamental components thereof; means connecting said amplifying circuit into said filter system; and a mixer connecting said filter system with said translating device.

12. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes of the chromatic scale, a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common output lead; means connecting the output leads into a filter system comprising a wave filter in the output lead of each separate switch group and formed and adapted to pass only the fundamental frequency components of waves in said output lead; and a mixer connected to all of said filters and to said translating device.

13. An electrical musical instrument employing generators producing waves of oscillations having tone frequencies for a range of more than an octave of notes of a musical scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common output lead; means connecting the output leads of said groups of switches into a filter system comprising a filter for and connected in the output lead of each separate switch group and formed and adapted to pass waves consisting essentially of the fundamental components of waves common to said group; and means interconnecting the filter system with said translating device.

14. An electrical musical instrument employing generators providing complex waves of oscillations at tone frequencies for a range of more than an octave of notes of the tempered scale; playing-keys, each thereof controlling an electric switch, switches controlled by respective playing-keys arranged in separate groups in which the switches in each group are connected with preassigned generators providing output waves at the tone frequencies of predetermined sequentially related notes, the switches of each separate group connected together by a common output lead; means connected to the output leads of respective switch groups for receiving waves from generators common thereto and isolating same from each other to prevent interaction between them; a wave filter system; an amplifier connecting said wave receiving and isolating means with said wave filter system; and a wave translating device connected in the output of said filter system.

15. The combination set forth in claim 14, in which said wave receiving and isolating means comprises an electron discharge device for each separate switch group, the same having a control grid connected to the output lead thereof and an output electrode, the output electrodes of all such electron discharge devices connected by a

common path in the grid circuit of said amplifier.

16. The combination set forth in claim 14, in which a mixer is interposed between and connected with said filter system and said translating device.

17. The combination set forth in claim 14, in which a mixer is interposed between and connected with said filter system and said translating device and connects said filter system with said translating device through respective decoupling resistances.

18. The combination set forth in claim 14, in which the translating device includes a power amplifier having a volume control device.

19. The combination set forth in claim 14, in which the filter system embodies filters respectively providing predetermined formant regions and the mixer is connected to said regions by respective conductors.

20. An electrical musical instrument employing an electrical network; a keyboard; generators of complex waves of oscillations for a range of more than an octave of notes; a wave translating device, the playing-keys of said keyboard having electric switches controlling transmission through said network of waves from selected generators; switches associated with respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators providing output waves having the tone frequencies of notes associated with sequentially related ones of said playing-keys, the switches of each separate group connected together by a common output lead; means connecting the output leads of the separate switch groups in said network and into respective filter systems through separate conductive paths and for preventing modulation between waves being conducted to said paths; a mixer connected with said filter systems and with said wave translating device for conduction to said device of any desired mixture of waves from said systems and having decoupling resistances through which waves forming any such mixture are adapted to be transmitted to said device.

21. The combination set forth in claim 20, in which the means connecting said output leads in said network and into said respective filter systems comprises a space discharge device for and connected in each output lead and has two output electrodes, the output electrodes of the respective space discharge devices providing separate series of electrodes in which those comprising one such series are connected to one of said conductive paths and those comprising the other series are connected to the other conductive path.

22. The combination set forth in claim 20, in which the means for connecting said output leads in said network and into said respective filter systems comprises a space discharge device for and connected in each output lead and having two output electrodes, the output electrodes of the respective space discharge devices providing separate series of electrodes in which the electrodes comprising one of said series are connected to one of said conductive paths and the electrodes comprising the other series thereof are connected to the other of said paths, and in which means are provided in the output leads of all switch groups for preventing interaction between same.

23. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes of the chromatic

scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device; switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group connected together by a common output lead; high vacuum tube isolators, each individual isolator having a grid circuit, a cathode circuit and two plate circuits, each of said isolators having its grid circuit connected with the output lead of one of said switch groups, the plate circuits of each of said tubes forming respective output paths for concurrent transmission of waves impressed on the grid circuit thereof from the output lead of a respective switch group; and means connecting the output paths from the plate circuits of said tubes into respective filter systems for producing waves differing from the waves in said output leads of said switch groups only in their harmonic composition above the fundamental frequency components thereof; and a wave translating device connected with said filter systems for conversion of the outputs thereof into audible sound.

24. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group connected together by a common output lead; means connecting the output leads of said groups of switches into a filter system employing separate filters, each of which forms and provides a predetermined formant region having an output conductor, said output-lead-connecting means comprising a path from the output leads of all switch groups connected in common with all of said filters; and a mixer having a plurality of individually controlled switches, each of which is connected to one or more of said conductors through decoupling resistances of relative values determining the amplitudes of outputs from said conductors; a power amplifier in which the mixer switches are connected; and a loud speaker connected in the output of said amplifier.

25. A musical instrument as set forth in claim 24, in which certain at least of said filters are of the band-pass type having a high coefficient of coupling and are adapted to pass fundamental frequencies and certain of their harmonic frequency components for the full frequency range of the instrument.

26. A musical instrument as set forth in claim 24, in which certain at least of said filters are of the band-pass type having high coefficient of coupling and in which the aforementioned formant regions respectively vary in width, sharpness and taper outside said regions.

27. A musical instrument as set forth in claim 24, in which a low operating current is applied to said generators, and in which amplifiers are interposed between and connected with the output leads of said switch groups and said filters.

28. The combination as set forth in claim 1, in which the means connecting the output leads

of said groups of switches in said filter systems comprises a twin-triode vacuum tube for each separate group of said switches and has the grids of the separate triodes connected in common and to the output lead of said switch group, the plate of one triode of said tube connected in one of said filter systems and the plate of the other triode of said tube provided with a plurality of branch paths connected in a resistive-capacitative mesh for suppressing certain of the higher harmonics of waves impressed on said branch paths, which said branch paths are connected in the other of said filter systems.

29. An electrical musical instrument employing generators producing stabilized, complex, output electrical impulses providing tone frequencies for more than an octave of notes of a musical scale; a keyboard, each playing-key of which controls an electric switch; switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing outputs having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common output lead; a power amplifier having input and output circuits, the output circuit of which has a loud speaker connected therewith; means individual to and connected with the output lead of each separate switch-group for receiving outputs of generators common only to said group and isolating same from outputs of generators common to any other switch-group and for dividing the received and isolated outputs into respective portions and concurrently impressing same on respective output paths connected with said means; means connected with certain at least of said output paths of the receiving and isolating means of each separate switch-group for modifying the waveforms of said portions of the outputs impressed on said paths; a series of amplifying stages, each individual amplifying stage connected in common to corresponding output paths of the respective receiving and isolating means and each thereof having an output conductor; and mechanism including a mixer connected with the output conductors of said stages and with the input circuit of said power amplifier.

30. The combination set forth in claim 29, in which an amplifying stage is connected to the output conductor of one of the first named stages and has an output path connected into the input sides of wave filters respectively providing predetermined formant regions in the audible frequency spectrum, and in which each of said wave filters is provided with an output conductor which is connected with said mixer.

31. An electrical musical instrument employing generators providing complex electrical impulses for a range of more than an octave of musical notes; playing-keys, each thereof controlling an electric switch, switches controlled by respective playing-keys arranged in separate groups in which the switches in each separate group are connected with preassigned generators providing outputs at tone frequencies of predetermined sequentially related notes, the switches of each separate group connected together by a common output lead; a filter system comprising separate filters providing respective predetermined formant regions in the audible frequency spectrum, the outputs from the output leads of all switch-groups connected in common to each of said separate filters; a mixer connected with said filters

to receive outputs therefrom and separate the output from any filter from the output of any other filter; means connected with said mixer for translating outputs from said separate filters into audible sounds; and means embodied in said mixer for selectively impressing the output from any filter of said separate filters on said translating means.

32. An electrical musical instrument having a plurality of stabilized generators respectively supplying electrical impulses which are rich in harmonics and embrace a range of more than an octave of notes of a musical scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device; switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard; means connected with the respective switch-groups for receiving the outputs therefrom and isolating the outputs in any group from outputs in any other group to prevent interaction therebetween, said output receiving and isolating means including at least one transmission path for each switch-group; an amplifying system having an input circuit and an output circuit, the input circuit of which is connected in common to the transmission paths of all said switch-groups; a wave filtering system comprising separate filters providing respective predetermined formant regions connected in common to the output circuit of said amplifying system and each having an output conductor; and a mixer in which said output conductors are embodied, said mixer having electric switches interconnecting the conductors with said translating device for selective transmission of the output of any conductor thereto.

33. The combination set forth in claim 1, in which said filter systems are respectively provided with output conductors for transmission of the outputs thereof and the mixer is provided with a plurality of electric switches, one, at least, of which is connected to a single conductor through a decoupling resistance and other thereof are connected to more than one of said conductors through respective decoupling resistances, all of said decoupling resistances being of predetermined values for establishing the relative amplitudes of outputs from said conductors.

34. An electrical musical instrument employing generators producing complex waves of oscillations, said waves providing tone frequencies for a range of more than an octave of notes of the chromatic scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common output lead; means connected to said leads for amplifying output waves therefrom; a filter system, means connecting said amplifying means into said filter system, said filter system having a set of filters producing output waves differing in wave form from each other, and a mixer connecting said filter system with said translating device.

35. An electrical musical instrument employing generators producing complex waves of os-

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oscillations having tone frequencies for a range of more than an octave of notes of the chromatic scale, a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group connected together by a common output lead; means connecting the output leads of said groups of switches into a filter system producing waves differing from waves in said output leads only in their harmonic composition above the fundamental frequency components thereof; and a mixer interconnecting said filter system with said translating device.

36. An electrical musical instrument employing generators producing complex waves of oscillations having tone frequencies for a range of more than an octave of notes of the chromatic scale, a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches controlled by respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the tone frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group connected together by a common output lead; a high vacuum tube isolator for each separate group of switches, each of said isolators provided with an electrode connected with the output lead of a respective group of switches and an electrode connected into a filter system producing waves differing from waves in said output leads only in their harmonic composition above the fundamental frequency components thereof; and a mixer interconnecting said filter system with said translating device.

37. An electrical musical instrument employing generators producing complex waves of oscillations, said waves providing tone frequencies

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for a range of more than an octave of notes of the chromatic scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common capacitative output lead; means connected to said leads for amplifying output waves therefrom; a filter system, means connecting said amplifying means into said filter system, said filter system having a set of filters producing respective output waves differing in waveform from each other, and a mixer connecting said filter system with said translating device.

38. An electrical musical instrument employing generators producing complex waves of oscillations, said waves providing tone frequencies for a range of more than an octave of notes of the chromatic scale; a keyboard, each playing-key of which controls an electric switch; a wave translating device, switches of respective playing-keys of said keyboard arranged in separate groups and connected with preassigned generators producing waves having the frequencies of notes associated with sequentially related playing-keys of said keyboard, the switches of each separate group of switches connected together by a common capacitative output lead; means connected to said leads for amplifying output waves therefrom; a filter system, means connecting said amplifying means into said filter system, said filter system having a set of filters producing output waves differing in wave form from each other, and a mixer connecting said filter system with said translating device, the capacitances in the output leads of the respective groups of switches being of respectively different capacities.

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