

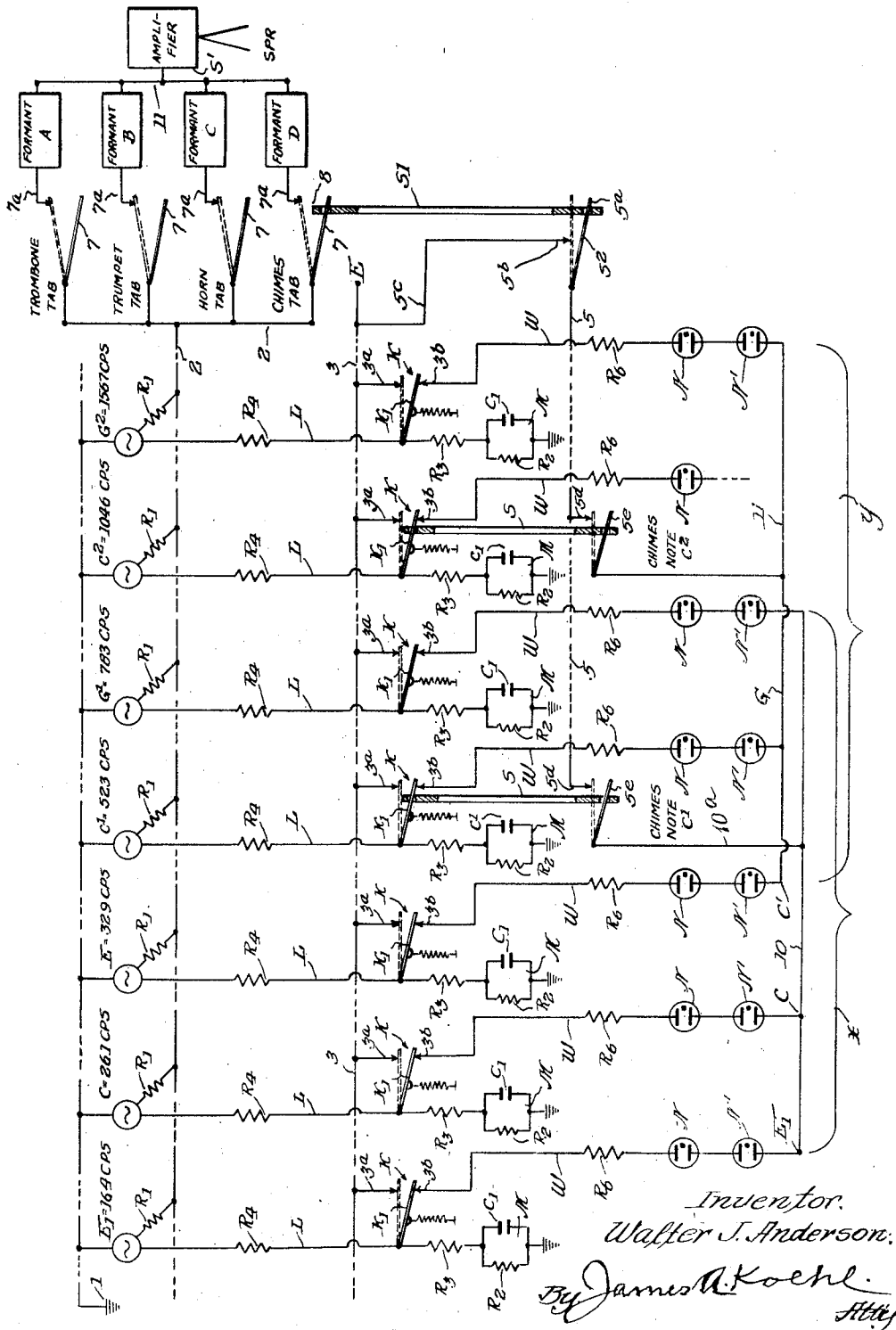
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ELECTRICAL MUSICAL INSTRUMENT

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ELECTRICAL MUSICAL INSTRUMENT

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This invention relates to electrical musical instruments and more particularly to an instrument for electronically simulating chime, bell and other percussive tones.

The invention is a development of instruments of the prior art in which space discharge devices provide sources producing output waveforms of tone signals at the vibration frequencies of different notes of the chromatic scale, which frequencies are available as desired from a conventional piano or organ keyboard when playing written music. An important feature of the invention finds expression in a new and improved method enabling the production of sustained organ-like and/or percussive tones from a common set of tone frequency sources and, whereby, on depressing a single playing-key to supply a work circuit with a frequency corresponding to the vibration of a selected note there will be concurrently mixed with it the outputs from others of said sources, the frequencies of which are harmonically related thereto, the waveform of the combined frequencies being instantaneously impressed on an output system, where, by wave-filtering techniques based on the formant theory, bell, chime and other percussive tones may be sounded. Assuming the keyed tone to be $C^1=523$ cycles per second, the concurrently impressed frequencies will be $E_1=164$ cycles per second; middle $C=261$ cycles per second and $G^1=783$ cycles per second. These combined frequencies are then influenced by the formant frequency range, the amount of emphasis in that range and the width of the frequency band involved. Thus there will be produced at an electroacoustic device in the aforementioned output system, a tone at the pitch of the keyed tone, plus those components necessary to produce a bell tone for note $C^1=523$ cycles per second.

Referring to the bell as a metal instrument, circular in cross section with one end closed and from which the bell is hung, the size, shape and weight of the bell varying greatly, the tone produced by striking gives one tone only, the pitch and quality, however, being determined by the shape, the type of metal or alloy, the thickness of the "sound bow" or thickened part of the rim, and other factors. A feature of my invention is the provision of means for producing bell and chime tones electronically with resulting audible effects closely similar to struck bells or chimes when sounding a given note, the coalescence of its pulses causing the bell or chime to divide into a number of vibrating segments. If the body is a bell, the vibrating segments are separated from each other by as many nodal lines running up from the "sound bow" to the crown of the bell, the result being that, in addition to the prime tone sounded at which the bell is pitched, there will be combined therewith audible vibrations related thereto as sub and upper harmonics thereof. Then too, in the sounding of bells and chimes, the audible effect has directly associated therewith the growth and decay of the resultant sound which starts and stops as a function of time. In carrying the invention into practice, new and improved means are provided to the end that this effect is obtained in a highly satisfactory manner by a unique system of electrical components and keying circuits.

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A further object of the invention is a low cost electronic system for faithfully simulating chime, bell and other percussive tones, which system is adapted to be readily incorporated in the electrical network of an electric organ embodying tone frequency sources and keying circuits enabling selective transmission of the outputs from said sources to an electroacoustic translating device for conversion thereof into audible sounds.

A still further object is the provision of a system enabling repetitious playing of the same note as often as necessary for the playing of music as written.

Another object is the provision of an electric organ employing a system of "stops" indicative of different timbres, including a "stop" indicative of a chime or bell tone, and means by which a waveform of signal voltage which is typical of a given musical instrument may be added, as desired, or at the will of the player to a complex waveform of signals typical of a bell or chime for modifying the bell or chime tone.

My invention will be more clearly understood from the following description and upon referring to the accompanying drawing wherein the figure is a diagrammatic illustration of one exemplified form of the invention embodied in the electrical network of an electric organ employing keying and timbre control circuits actuable from a conventional keyboard for selective transmission to a translating system of the outputs of tone frequency sources.

To avoid confusion in the electrical network in which my invention is incorporated, the accompanying drawing shows only seven tone frequency sources of a set of sources attuned to each other in diatonic succession. These seven sources are respectively designated E_1 , C , E , C^1 , G^1 , C^2 and G^2 , the frequencies of which are as follows:

$E_1=164$ cycles per second
 $C=261$ cycles per second
 $E=329$ cycles per second
 $C^1=523$ cycles per second
 $G^1=783$ cycles per second
 $C^2=1048$ cycles per second
 $G^2=1567$ cycles per second

To make for a clear understanding of the functional features of the invention, at the same time avoiding confusion otherwise resulting from duplication of similar mechanical features and elements, the disclosed system provides for playing only two chime or bell tones at the vibration frequencies of notes C_1 and C^2 and their harmonic frequencies, to wit:

Directly keyed tone $C^1=523$ C. P. S.

Indirectly and concurrently transmitted frequencies:

$E_1=164$ C. P. S.
 $C=261$ C. P. S.
 $G^1=783$ C. P. S.

Directly keyed tone $C^2=1046$ C. P. S.

Indirectly and concurrently transmitted frequencies:

$E=329$ C. P. S.
 $C^1=523$ C. P. S.
 $G^2=1567$ C. P. S.

The tone frequency sources employed in carrying my invention into practice may be any well-known type of space discharge device or its equivalent. One satisfactory form of device for producing square waves in the Eccles-Jordan divider circuit disclosed in United States Letters Patent to Langer, No. 2,533,821. I may use with equal success the system shown and described in my co-pending application, Serial No. 531,496, filed August 30, 1955. While the invention may be used separate and apart from an electric organ, another feature of the invention is the unique circuits and arrangements

of elements enabling adaptation of the invention to electric organs for more versatile musical effects by an inexpensive procedure allowing a common set of tone frequency sources to be employed both for the production of organ and orchestral tonalities and also tonalities typical of bells, chimes and other resonant and vibratile bodies. While various types of tone frequency sources can be used with good results, regardless of whether the output is a sine, sawtooth or square wave, I use, in either case and for most satisfactory results, a system founded upon the theory of formants in which different frequency ranges and emphasis upon certain frequencies are responsible for the tone color the ear receives. Any tone color may have more than a single formant and is attributed to the physical properties of a given instrument. This color, as it is received by the ear, is influenced both by the formant frequency range and the amount of emphasis in that range and the width of the frequency band. Thus a chart of different instruments would show that they have very pronounced formants, some with much wider formant ranges and less emphasis of the harmonics that fall in those ranges. The formant frequencies of the brass instruments become higher as the size of the horn bell decreases. The human voice has two formants. All vowels have a formant in the lower range and most vowels have one or more in the upper range. To imitate a tone whose formant is at or around 1000 cycles per second, the input spectrum would resemble a sawtooth, the succeeding harmonics being present with amplitudes inversely proportional to their orders, whereas the output spectrum would be similar in waveform except for accentuation of those frequencies in the region of 1000 cycles per second. In short, these formants are achieved electronically by wave filtering as taught by prior patentees. See: Vierling, United States Letters Patent No. 1,933,299 of October 31, 1933. The spectrum emphasis that has given excellent results in carrying my invention into practice shows a frequency range of approximately from about 800 to about 1400 cycles per second.

The aforementioned tone frequency sources are connected to a common ground 1 and to a common output conductor 2 via load resistors R1, and, as shown, said output conductor connects to an output system which includes a set of tabs or "stops" operating into selected formant regions A, B, C and D, coupled to an electroacoustic translating device S' by lead 11. Contactor 7 of a chimes tab switch 8 is linked by sticker S1 so that when said tab is in an "on" position, simultaneously therewith there will be engagement of contactor 7 with contact element 7a and engagement of contactor 5a of chimes switch S2 with its coactive contact element 5b.

As aforesaid, bell and chime tones are adapted to be elicited from the same keys of a keyboard that are used to play organ-like and orchestral tones, and in this connection it is noted that for each separate source E₁—G² there is a playing-key operated single pole double throw electric switch K connected in circuit with a respective source by a lead L in series with a series parallel mesh M comprising a condenser C1, leak drain resistor R2 and a protective resistor R3, the connection between said switch and said source being through a resistor R4 in said lead L.

At E is a source of electrical energy for selectively applying potential to the generators and to the gas content devices to be hereinafter described in complete detail, and, as illustrated, a conductor 3 from said source has longitudinally spaced apart contact elements 3a, such that there is one thereof for each of said playing-key operated switches K, the movable contactors K1 of which are engageable with respective contact elements 3a and adapted when disengaged therefrom to engage contact elements 3b.

At 5 is a conductor shown connected to a contactor

5a of an electric switch whose contact element 5b connects to conductor 3 via lead 5c in order that when said contactor and said element 5b engage each other, electromotive force is supplied conductor 5 from the aforementioned source of energy E. Spaced apart longitudinally from each other on said conductor 5 are contact elements 5d of electric switches whose contactors 5e are engageable with elements 5d, there being one such switch situated below and in the vertical plane of a respective playing-key operated switch K for tone sources C¹ and C². As previously set forth, the single figure in the accompanying drawing shows frequency combinations for chime tone notes C¹ and C². It accordingly follows that the system of tone frequency sources will necessarily include a complement of sources sufficient to supply to each keyed bell or chime tone a plurality of harmonically related frequencies from sources common to playing-keys in octaves lying both above and below those keys of the keyboard which determine the range of available bell and chime tones in their sequential order in the scale. Assuming the range to embrace notes C¹ through G², twenty sources will be necessary for the pitches identified by the positions of these notes in the scale, plus such number of additional sources required to be drawn on to supply the necessary harmonics for each individual pitch played at any instant, as will be understood from the description given earlier herein with reference to the harmonics required to be combined with frequencies, notes C¹ and C², and from the following more detailed description.

Brackets X and Y are representative of the pitch positions in the gamut of the instrument of two different combinations of pitches for producing keyed tones C¹ and C² and pitches which are harmonically related thereto. Bracket X includes in the combination tone sources E₁, C, C¹, and G¹. Bracket Y includes tone sources E, C¹, C², and G². Each contact element 3b has connected thereto a lead wire W having in series therewith one or more impedances in the form of gas content tubes N, N'. Interposed between said tubes and a respective contact element 3b of an associated lead W is a resistor R6. Leads W common to tone sources E₁, C, and G¹ (bracket X) are connected together by a common header 10. Similarly, leads W common to tone sources E, C¹ and G² (bracket Y) are connected to each other by a common header 11.

Now referring to playing-key C¹—523 cycles per second, it is observed that contactor K1 of switch K common thereto and contactor 5e of the underlying switch are connected together by motion imparting linkage means such as sticker S in order that contactors K1 and 5e will move simultaneously in response to motion of key K common to source C¹. Contactor 5e connects to header 10 by a conductor 10a. If, now, contactor 5a is closed against contact element 5b, and contactor K1 of key switch K common to tone source C¹ is moved onto contact element 3a, electromotive force will be supplied all gas content tubes in conductors W common to tone sources E₁, C, and G¹. The gas content tubes are preferably of the NE2 type employing two spaced apart cold electrodes. When the gas in the tubes is extinguished, the tubes are non-conductive, as would be the case when contactor 5a is open-circuited. When in this condition, tone signals from said sources can then be conducted to the output system by coaction of contactor K1 with contact element 3a for the production of tones other than those of the bell and chime varieties.

From the foregoing description it is appreciated that when the playing-key for note C¹ or C² is played, contactor K1 of switch K engages contact element 3a, thereby charging condenser C1 from source E, causing an audio signal from tone source C¹ or C², as the case may be, to be impressed on the common output conductor 2 via resistor R1. Assuming that contactor 5a is engaged

with contact element 5b, potential from source E is also applied to conductor 5. As contactors K1 and 5e are operated simultaneously when keying a tone, energy from source E is transmitted to tubes N and N', reduced, however, by the IR drop across the series-connected tubes in leads W and through resistors R6 in said leads. In this manner, condensers C1 common to a group of leads W are charged simultaneously with firing of the gas in said tubes. It accordingly follows that when a key associated with source C¹ or C², as the case may be, is operated, the signal from said source will be impressed on conductor 2 simultaneously with impressing on said conductor the outputs of sources common to the respective leads of said group of leads W. Assuming, now, that the operated key is associated with source C¹, then, in that event, and as these leads are conductive, output signals from sources E¹, C and G¹ will be impressed on conductor 2. In this manner, three sources providing harmonically related tone signals are mixed with signal output from source C¹ to provide a waveform of signals for a resultant bell tone, influenced, of course, by formant region D.

When contactor 5a is engaged with contact element 5b, motion is imparted to contactor 7 by the motion-transferring sticker S1, thereby causing contactor 7 to engage contact element 7a and establishing a complete circuit between conductor 2 and formant region D for emphasis upon components of said complex waveform of bell tone frequencies conducted to said region.

Contactors 5a is adapted to be operated manually. When contact 7 is engaged with element 7a of formant region D, any one of the "stop" contactors 7 that connect conductor 2 with said contactors and are coactive with associated contact elements 7a at formant regions A, B and C can be selectively close-circuited so that there may be mixed with the output of formant D the output of any desired one of formants A, B and C, thereby modifying the bell tone as may suit the taste of the individual player. Excellent results are had when the output from formant B (trumpet stop) is used concurrently with the output of formant D.

While I have shown four formant regions as comprising a timbre control system in which the individual regions are each constructed, designed and adapted to yield an output wave typical of a given musical instrument, there may be any desired number of said regions.

Pointing now to the functional purpose of condensers C1 in the meshes M in conjunction with load resistors R4 and generators E₁—G², it shall be understood that upon release of any keying element K1, the aforementioned charges on condensers C1 gradually dissipate through associated load resistors R4, causing the keyed generators to sustain the signal outputs through resistors R1 and to conductor 2 for a predetermined interval of time after a given key has been released, this simulating the hang-over of tone following the striking of a bell or chime.

It is also important to note that in addition to the function just pointed to, condensers C1 and resistors R4 constitute a time circuit for each key when playing the instrument for straightforward organ and orchestral tones—the charging and discharging of the condensers C1 controlling the rate of attack and decay as a function of time.

I particularly stress certain features of my invention in the disclosed combination of elements and the interconnection of said elements with each other and in circuit, such, for example, that the system of timbre controls (formants) influence waveforms of tone signals conducted thereto to produce in addition to waveforms typical of organ tones, tones typical of orchestral instruments, a waveform typical of bell and chime tones and are the result of simultaneous conduction to an electroacoustic translating device of a composite waveform comprising, in addition to a signal tone of the frequency associated with a single depressed key, signals from a plurality of sources, the frequencies of which are harmonically related to said tone.

Stated differently, each playing-key of a given number of sequentially related black and white keys of a conventional organ or piano keyboard, makes automatically available in a work circuit, a complex waveform comprising a first partial, a plurality of upper partials and a sub partial. Each complex waveform provided, in this manner, therefore, has a fundamental identifying its position in the scale of a useful number of sequentially black and white keys, generally not less than an octave. Certain of the keys comprise a predetermined range of bell or chime tones and may be played with resultant production of bell and chime tones, made possible by engaging contactor 5a with element 5b.

I also consider it new in the art and individual with me, the disclosed arrangement of timbre controls (formants) connected to a common input from a common set of tone frequency sources; the system of "stops" enabling signal voltage to be influenced by any selected timbre control (formant) and the outputs of different timbre controls to be combined, and the disclosed interconnection between switch 8, formant D and the movable contactor 5a, which latter, when moved to "on" position against contact element 5b, causes (1) ionizing energy to be conducted to a plurality of impedances N, N' to render paths in which they are connected effective for conducting signals to any one or more of the timbre controls A, B, C and D when any keying element within the bell tone range is activated.

Regarding terms used herein to describe certain elements, the term "stop" shall mean an electric switch mechanism embodying a tiltable or other manually adjustable tab or device denoting a tone of a given timbre, which tab or device, when in one condition of adjustment, enables conduction of signal voltage to a timbre control system for modification and subsequent translation thereof into sound of a given timbre. The term "keyed tone" shall mean a tone produced by withdrawing the output or outputs of one or more tone frequency sources according as a keyboard is played and converting same into audible sound. The present invention provides for keying tones the same as when playing a conventional organ. "Keyed tone" as used herein shall also mean producing a complex wave from a plurality of separately produced and harmonically related waves to form a single complex wave when depressing a single playing-key. The term "formant" shall mean a frequency range in which the harmonic components of a complex wave are prominent relative to the harmonics of other frequency ranges, the tone color as it appears to the ear being influenced by the formant frequency range, the amount of emphasis in that range and the width of the frequency of a given band. In the instant case, a complex wave containing all necessary components for bell and chime tones is first formed and then altered by wave filtering to emphasize certain of the components.

What I claim as my invention is:

1. In a musical instrument having resiliently mounted depressible playing-keys, a set of sources producing audio signals at harmonically related frequencies; a signal conductor connected in common to said sources; an output system connected to said signal conductor and including timbre control means and an electroacoustic translating device coupled thereto; certain at least of said playing-keys each having a first electric switch and a second electric switch for simultaneous operation thereof by the key from an open-circuited condition when the key is raised to a close-circuited condition when the key is depressed, all others of said keys each having associated therewith only a single electric switch for operation thereof from an open circuit condition when the key is raised to a closed circuit condition when the key is depressed; circuits connecting the first switches of said pairs of switches of said certain keys and the single switches of said all others of said keys to preassigned ones of said sources for impressing on said conductor the outputs of any desired ones of said sources; means actuable as desired for

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rendering the second switches of said pairs of switches of said certain keys respectively electrically active and inactive; and selectively actuatable means adapted when any one of said certain keys is depressed, and the second switch of the pair of switches common thereto is electrically active, to impress on said signal conductor the outputs of preassigned ones of said sources concurrently with impressing on said conductor the output of a source common to the first switch of said depressed key.

2. In an electrical musical instrument, a series of tone frequency sources respectively producing audio output signals corresponding to the vibration frequencies of more than an octave of notes of the chromatic scale; an electrical network in which said sources are connected, said network including an output system having an audio translating device, a set of selectively actuatable switches, a wave filter for and connected to each separate one of said switches and to said translating device, a common conductor connecting said sources to said switches, depressible playing-keys, each key having an electric switch operated thereby and connected in circuit to an assigned one of said sources enabling conduction to said common conductor of the output thereof upon depression of said key, certain of said keys each having an additional electric switch operated thereby and connected to others of said

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sources, and means in said network coactive with said additional switches and said selectively actuatable switches for rendering the latter electrically effective to cause conduction to said common conductor of the outputs of others of said sources, said means comprising, electron discharge high impedance devices connected in said network and to preassigned ones of said tone frequency sources and to said additional switches adapted when not electrically activated to block conduction to said common conductor of the outputs of said other tone frequency sources, and wherein, means including mechanical linkage connects one of the switches of said selectively actuatable switches to said additional playing-key operated switches to render said additional switches and said electron discharge devices electrically effective to unblock flow of the outputs of said other tone frequency sources to said common conductor.

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