Oct. 6, 1959 E. SCHREIBER 2,907,244

ELECTRIC MUSICAL INSTRUMENT

Filed Jan. 31, 1956 5 Sheets-Sheet 1

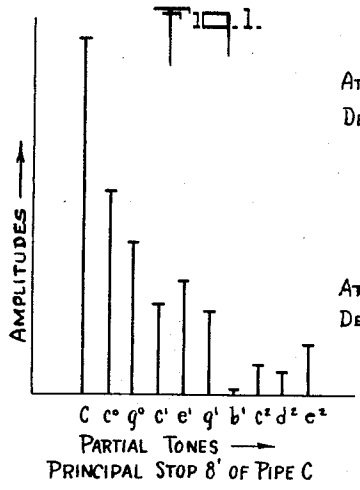
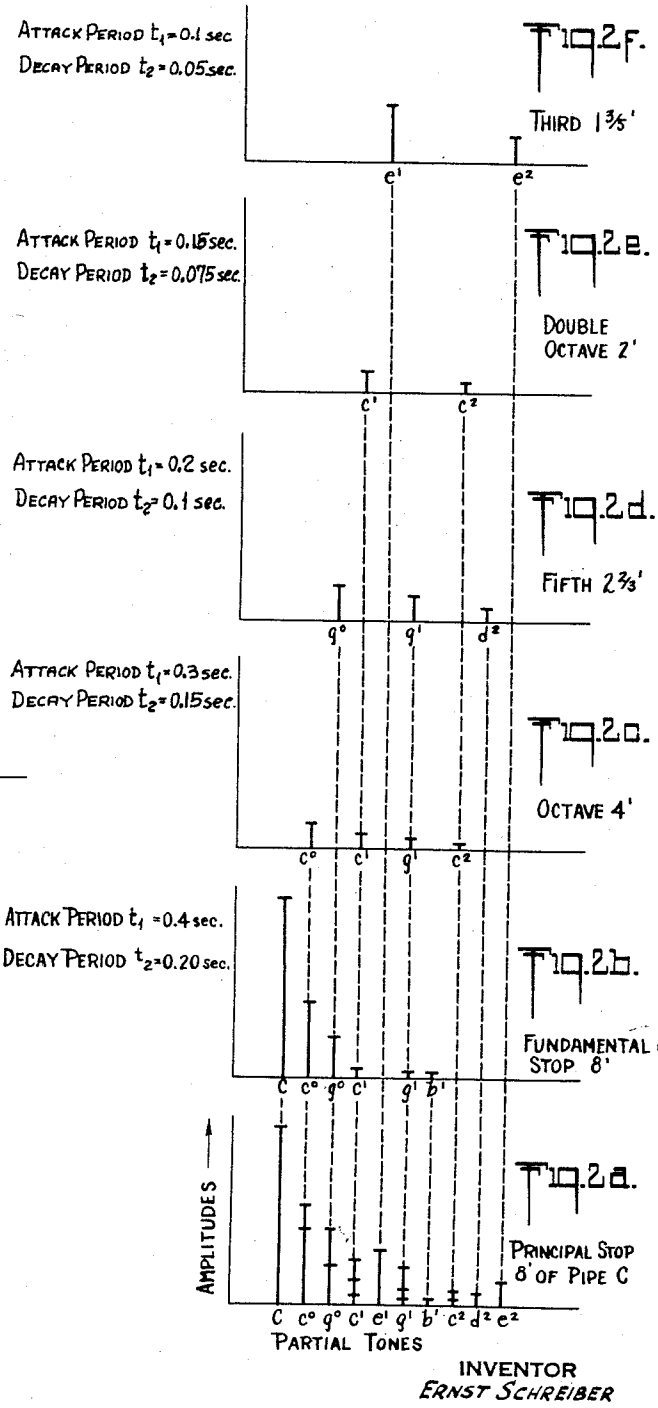


Fig. 1.

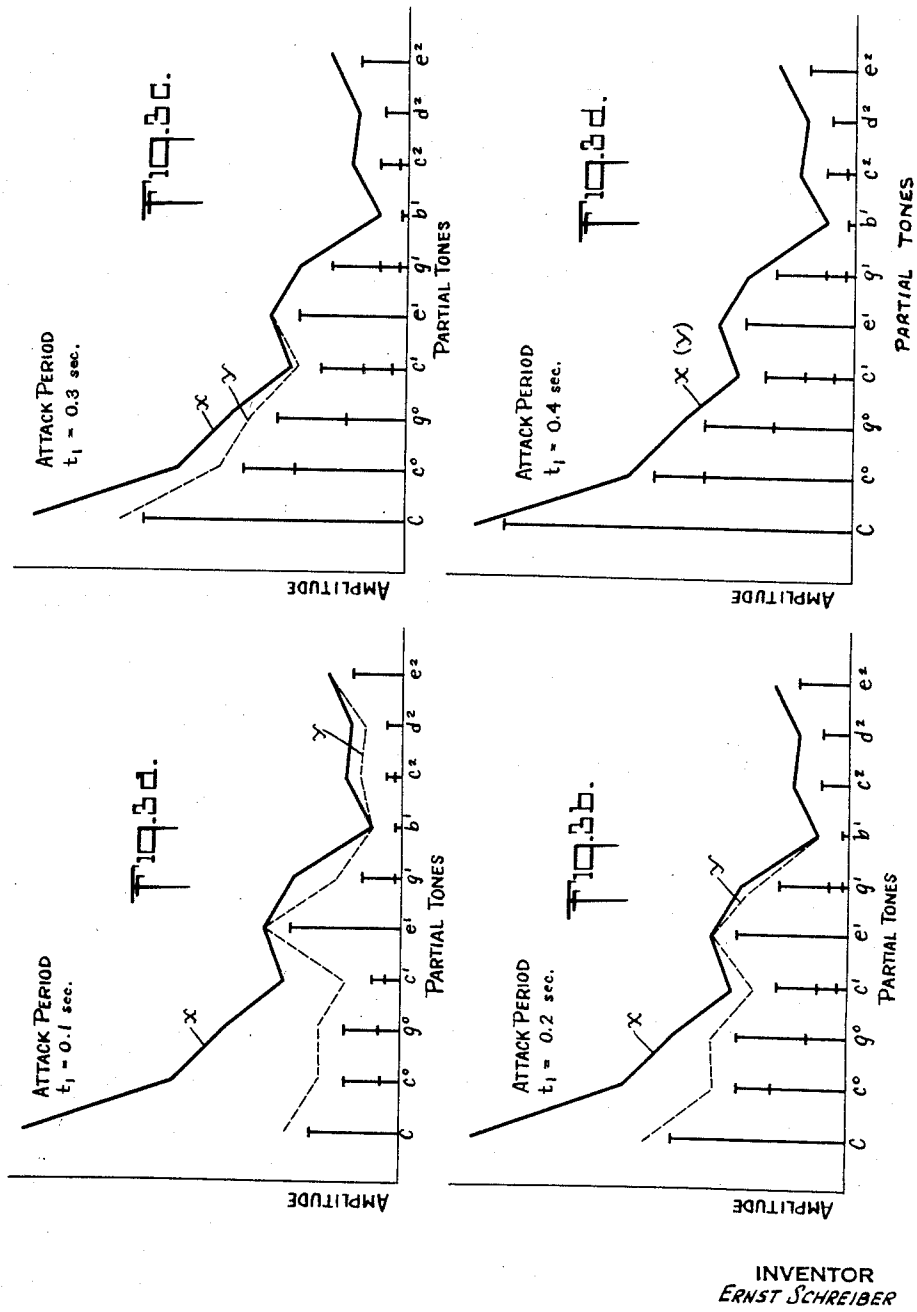


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ELECTRIC MUSICAL INSTRUMENT

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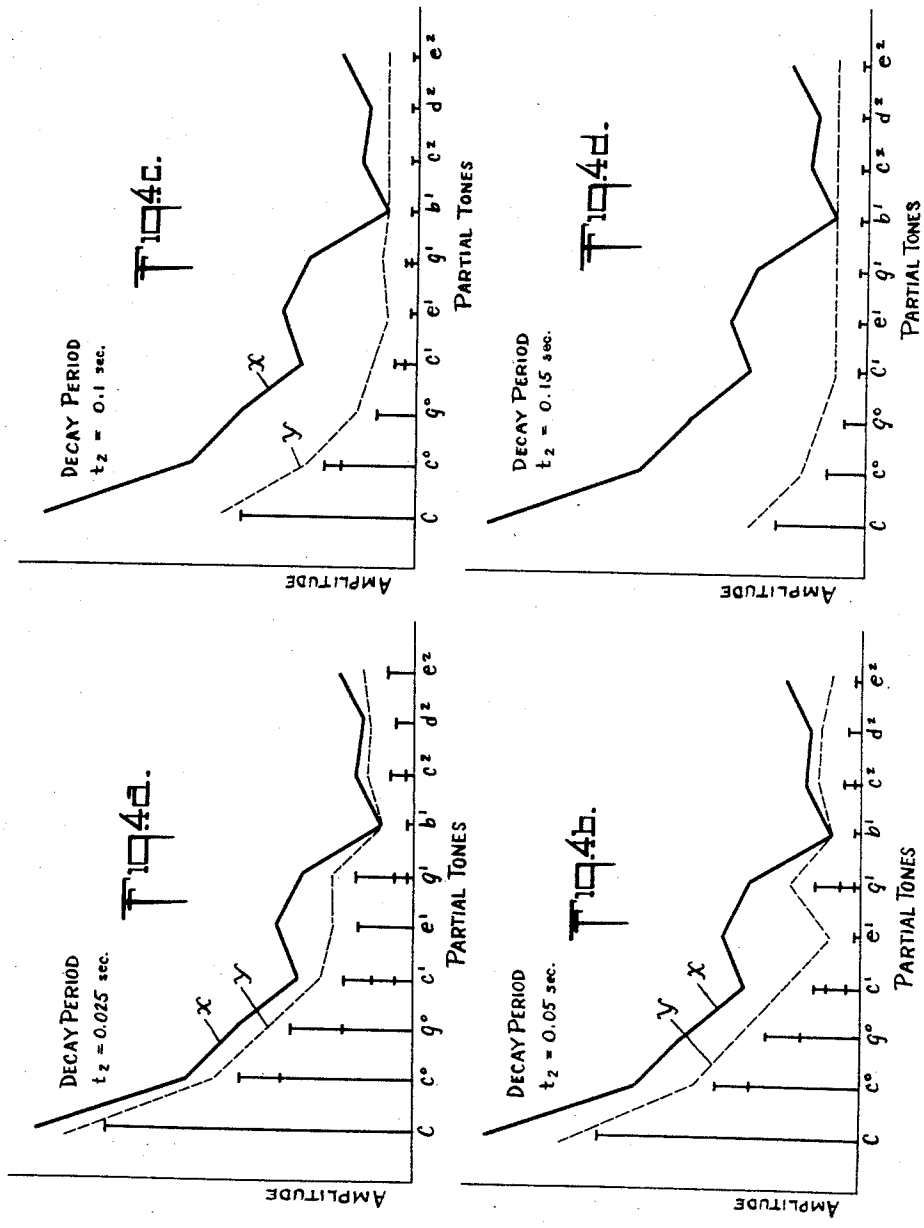


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ELECTRIC MUSICAL INSTRUMENT

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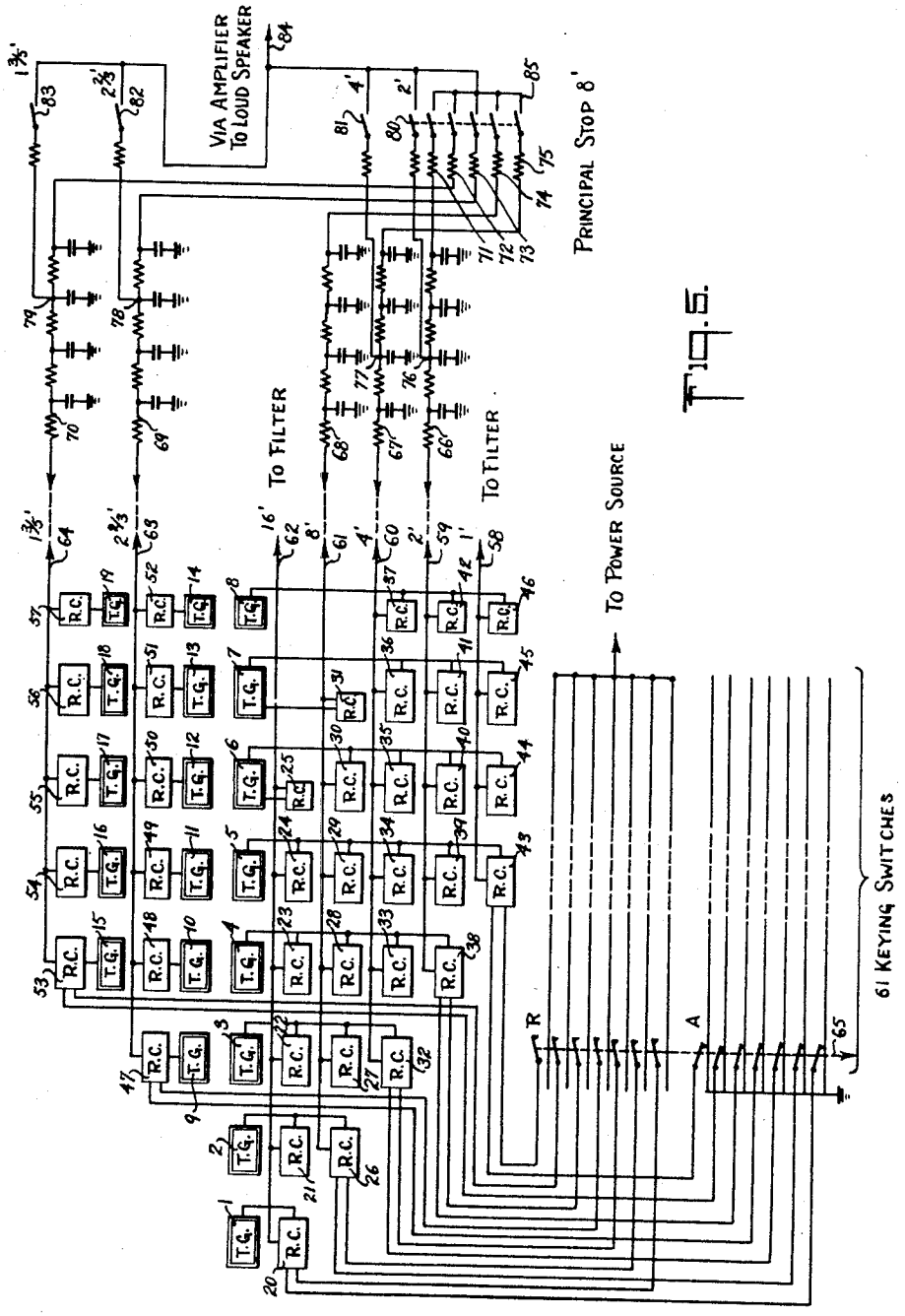


FIG. 5.

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Fig.6c.

ATTACK PERIOD $t_1 = 0.3$

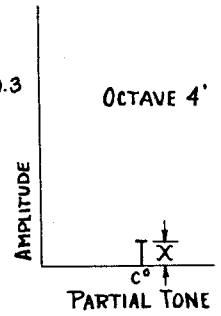


Fig.7c.

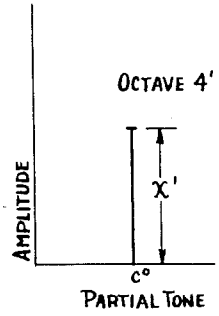


Fig.6b.

ATTACK PERIOD $t_1 = 0.4$

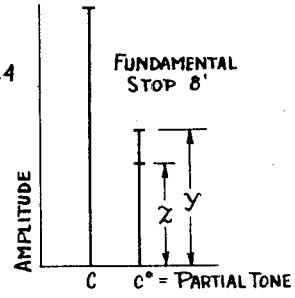


Fig.7b.

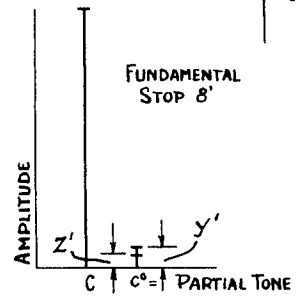


Fig.6d.

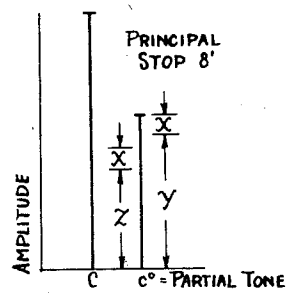
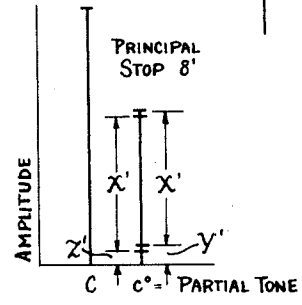


Fig.7d.



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ELECTRIC MUSICAL INSTRUMENT

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Application January 31, 1956, Serial No. 562,471

Claims priority, application Germany May 9, 1955

3 Claims. (Cl. 84—1.19)

The present invention relates to electrical musical instruments, and more particularly to electrical organs.

It is an object of the present invention to reduce the number of switching contacts required for the electrical musical instruments or an organ according to the invention.

It is another object of the present invention to imitate sound spectra in all stop positions of an electric organ.

It is a further object of the present invention to imitate the natural sound of the tones produced by an organ including the transient phenomena thereof.

Other objects and advantages of the present invention will become apparent from the following detailed description thereof in connection with the accompanying drawings showing, by way of example, an embodiment of the present invention. In the drawings:

Fig. 1 is a graphical representation of the sound spectrum of the principal stop belonging to the pipe C of a Silbermann organ which has to be synthetically imitated,

Figs. 2*a*–2*f* are graphical representations showing the operation of the switching arrangement according to the invention with respect to the building up periods, the dying down or decay periods, or the transient periods,

Figs. 3*a*–3*d* show time diagrams of the building up of transients, of all partial tones from the various stop positions,

Figs. 4*a*–4*d* show similar diagrams for the decay periods,

Fig. 5 is a wiring diagram of an electric organ according to the present invention, and

Figs. 6*a, b, c,* and Figs. 7*a, b, c,* are graphical representations of two differentiating cases of the building up tansients of the partial note c^0.

Before describing the drawings in detail it is advisable to insert some preliminary remarks.

The first scientific investigation relating to the analysis of instrumental sounds was carried out on the basis of the accoustical resonance. With the sound analyzers designed for this purpose it was found that the sounds contain partial tones of a definite structure.

The only musical instrument which produces, particularly in deeper tone positions, an almost pure tone without any appreciable components of harmonics is the flute having a sharp edge over which the air current generated during blowing moves at a constant speed. By the resonance of the air column the air current inside the flute is compelled to change from a pressure minimum to a pressure maximum without attaining the zero value. The sound consists mainly of the fundamental tone. Since the air current changes approximately according to a sinusoidal law, only a few harmonics are present. This specific behavior of the flute is aided by the fact that the boring of the flute is cylindrical with the same diameter over the entire length thereof. In consequence thereof the air column has at all places the same resonant frequency. The subdivision of the flute or its air column

into equal distances is not arbitrarily chosen since a resonance is generated not only by an air column having the length corresponding to one wave length but also by air columns having a length corresponding to one half, a quarter or even a smaller fraction of a wave length. In this respect the air column in a flute behaves like an electric resonance line. In an organ flute these conditions are changed somewhat because the air current generates a periodical separation of eddies at the sharply defined edge of the upper lip which takes a course which has the form more of a saw-tooth than a sine wave so that the sound has a higher content of harmonics.

In flutes with a conical boring or in Boehm flutes and particularly in reed flutes these conditions change fundamentally. The air current takes a completely saw-toothed course having a slow ascent and a suddent descent. Since a saw-tooth contains a large number of harmonics and the amplitude of the vibration decreases proportionally to the ordinal number thereof, the content in harmonics has to be larger in this case. The number of generated harmonics and the ratios between the same depend on the form and size of the organ flute and on the material thereof.

Recent investigations have led to the realization that the sound character of a musical instrument depends on a number of other factors than the type and the number of present harmonics of a fundamental. Only after developing the so-called formant theory was it possible to discern all the influences determining the sound character of a musical instrument. This shall be illustrated further with respect to a reed type of the clarinet stop of an organ. Under the influence of the tongue of the pipe the air current has practically a saw-tooth shaped course whereas the length of the air column determines the fundamental resonance and therefore the fundamental tone. Due to the conicity of the pipe boring the individual sections of the air column show different resonance points, so that the air column is subdivided into different parts for the higher frequencies being the harmonics of a fundamental. Thus certain harmonics find resonance points and are more or less emphasized. The material from which the pipe is made has an influence which may be characterized by an underscoring factor q which determines the strength of the emphasis of the resonant harmonics. The amount of the underscoring and the absorption is different at the various frequencies.

From this follows that each pipe body has a resonant frequency of its own which depends on the mass and the design of the body. If the air column is excited by an air shock a damped periodic wave train is obtained which is determined by its own resonant frequencies. These resonant frequencies are as a rule higher than the fundamental of the pipe.

According to this formant theory the natural resonant frequency of the pipe body denoted as formant frequency is not in a harmonic ratio to the fundamental of the pipe. The resonance of the body emphasizes the harmonics in addition to the small dampened wave train generated by the sudden excitation of the air column, the harmonics having frequencies corresponding to the resonant frequencies of the pipe body or being close to the same. Thus it is seen that in this case it is the question of fixed formant frequencies.

In electrical or electronic musical instruments, particularly organs, two different methods are used for producing the numerous tone colors. One of these methods is well known as the additive sound formation or synthetic method. It also may be called a synthesis of the harmonics and produces predetermined tone colors which are generated by admixing sine waves corresponding to a fundamental, the desired harmonics belonging to the fundamental. The second method is also synthetic and

is based on the formant theory and may be characterized as a subtractive method or reduction principle. This method consists in that by means of electrical components the acoustical conditions of a musical instrument, for instance an organ pipe are imitated. The fundamental may be taken from a saw-tooth generator. One or more resonant circuits imitate the natural resonance of the body of the instrument or pipe. A filter arrangement weakens or strengthens various portions of the frequency spectrum according to the resonant points of the body. By means of differential connections the wave may be transformed into series of well defined impulses in order to obtain certain sound effects.

Thus it is seen that a fundamental difference between the two methods consists in that according to the first method the sound is synthesized from the components thereof whereas according to the second method a wave containing all possible components, is generated, those frequencies which are not needed being suppressed. Practically another difference exists: in the subtractive sound formation fundamentals may pass a simple filter arrangement for a certain tone color. Since the formant frequencies and the accentuation or attenuation do not change, no matter which fundamental pitch is adjusted, each final tone has its characteristic wave form. Thus it is seen that the wave forms of, for instance, three fundamentals of the same stop differ from each other. The same is the case with most types of acoustical organs except the pipes of the principal register and the octave shifts thereof (open cylindrical flue pipes).

In the additive tone formation, however, each fundamental of a stop of the organ has the same components of harmonics which are adjusted once and for all. For instance, at a given adjustment the sound may have the following components: 50% fundamental (first harmonic), 25% second harmonic, 25% third harmonic. In this case every tone of the key-board has the same wave form. As mentioned hereinabove, this is approximately correct for the principal register and the octaves thereof. An electrical or electronic organ may thus according to the additive sound synthesis imitate only a few stops of the acoustic organ approximately whereas this is accomplished in so complete a way by the subtractive method that all sounds may be imitated without difficulty.

In order to imitate the transients of an acoustic organ in an electrical organ it should be taken into consideration that the partial tones reach their final amplitudes at different times. This feature may be electrically imitated without difficulty in the additive sound formation since the partial tones are generated individually in different tone generators. Therefore it may be achieved without difficulty to impart the desired course with respect to time to each of the generated partial tones by means of control members before the mixing stage. However, for the reasons set forth hereinabove the additive tone formation does not allow a perfect imitation of the stops except the principal stop and the octaves thereof.

It would be possible to do in the additive tone formation without an adjustment depending on the end amplitude of the individual partial tones for producing the spectrum, and instead to impart an equal amplitude to all partial tones, or to adapt the synthesis of the harmonics to a saw-tooth oscillation. These partial tones added by means of the mixing transformer which correspond already to the time course of the building up transient might then be sent additionally through formant filters in order to obtain stable formant frequencies. However, this procedure involves the disadvantage of an uneconomical expendiutre for switching contacts which carries with it a prohibitive lack of operational safety. For instance, in order to imitate approximately flue pipes rich in overtones or reed pipes, at least 25–30 partial tones are required. This would mean for the additive method that only for this purpose 25–30 switching contacts have to be provided per key.

The subtractive tone formation imitates all sounds of an organ completely, however, it is impossible to produce individually partial tones, on the contrary the fundamental is generated simultaneously with all partial tones.

The present invention solves the problem to imitate sound spectra in the most perfect manner at all stop positions of an organ under combination of the advantages of the additive and subtractive tone formations without incurring thereby the defects described hereinabove or the necessity of putting up with a considerable expense for switching contacts. This object is attained according to the present invention by preforming from an oscillation rich in harmonics, for instance a saw-tooth oscillation, by means of subtractive tone formation into sound spectra poor in harmonics, in at least two or more stop positions, and combining subsequently these sound spectra by means of additive tone formation staggered in time to a perfect sound spectrum with indication of the transients. In this way a natural imitation of the sounds of an organ is obtained under inclusion of all transients, namely building-up transients, decaying transients and transitions between stationary sounds.

Referring now to the drawings in detail, Fig. 1 shows a sound spectrum of a principal stop of the pipe C of a Silbermann organ which is to be imitated by an electrical or electronic organ.

In Fig. 2*a* this sound spectrum is represented on a smaller scale for the principal stop of the pipe C. The spectra shown in Figs. 2*b*–2*f* arranged above the spectrum shown in Fig. 2*a* represent, respectively, the fundamental stop 8′ having a building-up transient period $t_1=0.4$ second and a decay period $t_2=0.2$ second, the octave 4′ with a building-up period $t_1=0.3$ second and a decay period $t_2=0.15$ second, the fifth $2^2/3'$ with a building-up period $t_1=0.2$ second and a decay period $t_2=0.1$, the double octave 2′ with a building-up period $t_1=0.15$ second and a decay period $t_2=0.075$ second, and the third $1^3/5$ with a building-up period of $t_1=0.1$ second and a decay period $t_2=0.05$ second. The building-up and decay periods are controlled for each tone in the respective adjusting members by the time constant members thereof.

The final spectrum according to Fig. 2*a* is composed additively from the spectra shown in Figs. 2*b*–2*f*. According to Fig. 2*a* the first partial tone C (fundamental) comprises only a single component of the tone C in the fundamental stop 8′ according to Fig. 2*b*. The second partial tone c^0 is composed of the second partial tone c^0 of the fundamental stop 8′ shown in Fig. 2*b* and the first partial tone c^0 of the octave 4′ according to Fig. 2*c*. In an analogous manner the composition of all remaining partial tones g^0, c^1, e^1, g^1, b flat ^{1}, c^2, d^2, and e^2 may be read from Fig. 2*a* in connection with Figs. 2*b*–2*f*. For instance, the partial tone c^1 is the sum of three partial tones, namely the fourth partial tone according to Fig. 2*b*, the second partial tone according to Fig. 2*c*, and the first partial tone according to Fig. 2*e*.

It would be possible to derive from the tone generators the fundamentals of the fifth and third stops according to Figs. 2*d* and 2*f*, these fundamentals being present in tempered pitch. However, this would lead to strong beats between the harmonics which would have a most adverse effect on the sound. Therefore it is preferable to generate these harmonic stops (fifth and third) in pure pitch by separate tone generators according to the pattern of a pipe organ. Only if the fifths and thirds are pure a genuine change of timbre of the primary sound is obtained.

The addition of the partial tones from the spectra of Figs. 2*b*–2*f* is carried out over a period of time, that is, for instance, the thirds e^1, e^2 have reached the final value of the amplitude 0.1 second after the depression of the key (Fig. 2*f*), whereas all other partial tones are still in the process of being built up. Thus after 0.1 second the partial tones g^0, g^1, and d^2 of the fifth stop $2^2/3'$ (Fig.

2*b*) have only reached 50% of their final amplitudes since the building-up period is $t_1=0.2$ second. At the same time the partial tone g^0 of the fundamental stop **8'** (Fig. 2*b*) being identical with the partial tone g^0 of the fifth stop (Fig. 2*d*) has reached only 25% of its final amplitude since the building-up period of the fundamental stop **8'** amounts to 0.4 second as mentioned hereinabove. The values correspond to the actual synthesis of the sound as derived for the individual partial tones in a pipe organ.

The build-up time and the summation of the amplitudes of the building-up phenomenon of all partial tones from the different stop positions is graphically shown in Figs. 3*a*–3*d*, respectively, for the times 0.1, 0.2, 0.3, and 0.4 second and the tone C of the principal stop **8'**. All other tones of this stop show different times which yield also a different time curve of the sound synthesis. The corresponding graphical representations which would include for the principal stop **8'** alone altogether sixty-one tones for a key-board from C to c^4 has not been shown for simplifying the drawing. The different times needed for this purpose are generated by time constant members of the corresponding adjusting members of these sixty-one tones. By a corresponding addition of the available seven stop positions **16'**, **8'**, **4'**, **$2^2/3'$**, **2'**, **$1^3/5'$**, and **1'** and the various time periods, practically all characteristic phenomena of all stops may be imitated synthetically. The full lines represent the envelopes x of the stationary state, which is reached after finishing the building-up process whereas the dotted lines are the envelopes y of the building-up process at the intermediate times given on top of Figs. 3*a*–3*d*. In Fig. 3*d* the two envelopes x, y coincide because the building-up process is finished as to time, the stationary state of the sound having been reached.

From Fig. 3*a* to 3*d* it may be seen that in building-up the sound spectrum the higher partial tones reach earlier the final amplitudes thereof than the fundamentals and the deeper partial tones.

Referring now to Figs. 4*a*–4*d* of the drawings the curves denoted by x and shown in full lines are the same as the corresponding curves shown in Figs. 3*a*–3*d*, for the tone C of the principal stop **8'**. However, the curves denoted by y and shown in dotted lines correspond to the transition periods occurring at depressions of the same key taking place shortly after each other. As shown in Fig. 4*a* only 0.025 second have lapsed after the release of the key whereas according to Figs. 4*b* and 4*d* the intervals amount, respectively, to 0.05 second, 0.1 second, and 0.15 second. The final value is assumed to have been reached after 0.2 second, at which moment the sound has definitely decayed. The period of decay is longest for the deeper partial tones and the fundamental as will be clear from a comparison of the envelopes shown in dotted lines in Figs. 4*a*–4*d*. This corresponds exactly to the conditions prevailing in a pipe organ. The absolute decaying time is of course largely dependent on the acoustical conditions of the auditorium and on the reverberation time of the same.

The sound transients are subjected to the following conditions: at the releasing of a key the decay period with its transient starts. When before the lapse of the decay period the same key is depressed once more the decay transient is discontinued prematurely and at the same time a building-up transient begins which is shortened in time and characterized in that it does not begin with the amplitude zero but with that amplitude at which the decay transient of the preceding depression of the same key has been broken off.

Referring now to Fig. 5 an embodiment of an electric circuit is shown which allows to realize the sound spectrum analyzed in Figs. 1–4 with the transients thereof. It should be noted again that this embodiment is limited to the spectrum of the principal stop **8'** of the pipe C in order to simplify the drawing. For each tone of the stop an adjusting member is provided which regulates as to time the transients associated with the tones.

As shown in Fig. 5 seven octaves of tones in tempered pitch are arranged with the tone generators **1–7**. As it is well known twelve semitones belong to each octave so that eighty-four tone generators are required altogether. An aditional tone generator **8** is provided for the C-octave. Five octaves with the tone generators **9–13** represent the fifth stop **$2^2/3'$** which is purely tuned whereas the octaves having the tone generators **1–7** are tuned in tempered pitch. For the fifth octave again an additional tone generator **14** is provided. Four octaves with the tone generators **15–18** represent the third stop **$1^3/5'$**, an additional tone generator **19** being provided for the third stop which is also purely tuned.

For each of the twelve tone generators of each octave a control member is provided. In Fig. 5 only one tone generator is shown for each octave and correspondingly only one control member is shown for each octave.

The key board of each manual of the organ extends over sixty-one keys from C to c^4. To the corresponding tone generators **1–6** control members **20–25** are assigned, respectively, in order to control the tones in the **16'** stop positions. The control members **26–31** are assigned to the **8'** stop whereas the control members **32–37** belong to the **4'** stop. The control members **38–42** belong to the **2'** stop and the control members **43** to **46** to the **1'** stop. It should be noted that in the **2'** stop one octave of tone generators and in the **1'** stop position two octaves of tone generators are missing which would generate the tones of these stops in the last octaves of the manual. The missing octaves of tone generators are replaced according to the pattern of pipe organs by allowing the uppermost octave to repeat itself once or several times.

The control members **47–52** belong to the fifth stop **$2^2/3'$** and the control members **53–57** to the third stop **$1^3/5'$**. All control members are associated in correspondence with the stop position thereof with the bus bars **58–64**, for instance, the control members **20–25** with the bus bar **16'**, the control members **26–31** with the bus bar **8'**, etc.

The keying is shown in Fig. 5 only for the tone C in order to simplify the drawing. In the blueprint for a manual sixty-one keying switches **65** would appear and each keying switch has seven make contacts A and seven rest contacts R. When the keying switch **65** is actuated the corresponding control members of the key C are controlled in seven stop positions by means of the make contacts A. In this case the following tone frequencies appear on the bus bars **58** to **64**: on the bus bar **58** appears the tone c^2, on the bus bar **59** the one c^1, on the bus bar **60** the tone c^0, on the bus bar **61** the tone C, on the bus bar **62** the tone c^1, on the bus bar **63** the fifth g^0 and on the bus bar **64** the third e^1. By means of the rest contacts R the back keying is controlled for determining the decay and transition transients.

The tone generators **1–19** produce a saw-tooth shaped voltage having a high proportion of harmonics. The saw-tooth shaped voltages keyed by means of the control members and supplied to the bus bars **58–64** are guided over filters effecting the tone formation. The filters are partly formant filters and include singly or in combination low pass filters, high pass filters, band pass filters, and resonance members. Formant filters are resonance members having stationary tuning frequencies. In Fig. 5 only low pass filters are shown which are required for generating the sound spectrum shown in Fig. 1. Thus only one filter chain **66–70** is shown for each of the stops **8'**, **4'** **$2^2/3'$**, **2'** and **$1^3/5'$** in correspondence with the sound spectra shown in Figs. 2*b*–2*f*. The attenuation curve of each filter chain is chosen so as to generate amplitude distributions of the harmonics in the single stop positions according to Figs. 2*b*–2*f*. The proportions of the amplitudes of the spectra according to Figs. 2*b*–2*f* are controlled or dosed wtih respect to one

another by means of resistors 71–75 so that the addition of these amplitude proportions result in the principal stop synthetically to be imitated and shown in Figs. 1 and 2*a*; whereas the time addition effected according to Figs. 3*a* to 3*d* corresponding to the building-up process shown in Figs. 4*a* to 4*d* represents the decay transients or the sound transitions. Thus first a subtractive tone formation according to the analysing principle is effected and then the individual stop positions having different building-up and decay periods are additively mixed to the desired pattern of the total sound.

The filter chain 66–70 may be employed at the same time for representing other sounds. This is effected by means of tappings 76–79 arranged in the various sections of the multi-section filter chain. By these tappings the harmonic content of the formed tone is changed. The tappings may be provided at any point of the filter chains and used either directly in combination with one or several stops 80–83 or indirectly in combination of stops similar to the principal stop 85. A collecting line 84 leads from the stops to the preamplifier (not shown) of the loud speaker (not shown).

The connection according to the invention enables a natural limitation of the organ sounds to be made by the application of the subtractive tone formation, whereas by the subsequent additive tone formation staggered as to time the transients, that is the building-up transients, the decay transients and the sound transients are imitated in a completely natural manner.

Since the ratio of the building-up transients, for instance of the partial tone c^0 of the 8′ stop according to Fig. 2*b* and the partial tone c^0 of the 4′ stop shown in Fig. 2*c* is fixed by the building-up periods thereof amounting to t_1=0.4 second and t_1=0.3 second, respectively, fine differentiations between the building-up periods t_1 cannot be made. However, this is just what is needed in order to obtain certain sound effects. For instance, in a certain sound spectrum a building-up period t_1=0.35 second is required for the partial tone c^0 of the complete sound spectrum according to Fig. 2*a* although for the additive synthesis of this perfect partial tone an imperfect partial tone c^0 is used which is taken from the 8′ stop having a building-up period of 0.4 second. Thus the mentioned requirement of a differentiation cannot be met since the building-up period is fixed unchangeably to 0.4 second.

In order to obtain all the same a differentiation of the building-up period of, for instance, 0.4 for the complete partial tone c^0 according to Fig. 2*a* the present invention provides that the ratio of the amplitude of the partial tones imperfectly preformed in the individual stop positions is changeable without changing the fixed building-up periods for the individual stop positions and without influencing the fundamental, if any, of the stop position concerned.

The differentiation of the fixed building-up period according to the invention shall be explained with reference to the diagram shown in Figs. 6*a*, 6*b*, 6*c*, and 7*a*, 7*b*, 7*c*, showing two examples of differentiating the building-up transient periods of the partial tones c^0. According to Fig. 6*c* the imperfect partial tone c^0 reaches the amplitude value x after a period of 0.3 second at a time at which the amplitude y of the imperfect partial tone c^0 according to Fig. 6*b* has only reached ¾ or 75% of its final value because for completely building-up this amplitude y the time t_1=0.4 second is needed. The amplitude of the partial tone c^0 shown in Fig. 6*a* has thus the partial value z after 0.3 second. The amplitude of the partial tone c^0 of the perfect final sound spectrum according to Fig. 6*a* is composed after 0.3 second of the sum of x and z whereas the final amplitude has the value $x+y$ after 0.4 second.

The ratio $x:y$ is changed according to the invention without changing the building-up periods of the imperfect partial tones. The partial tone c^0 in the 4′ stop (Fig. 7*c*) reaches its end amplitude x' after t_1=0.3 second. At this moment the amplitude of the partial tone c^0 in the 8′ stop (Fig. 7*b*) has only reached ¾=75% of its final value y' because for a complete building-up of this amplitude the time t_1=0.4 second is required. In order to be able to build up the perfect final tone in the principal stop 8′ according to Fig. 7*a* this final value y' is smaller than y by the difference of x' and x. Thus the partial amplitude y' has the value z' after the lapse of 0.3 second. In the differentiating case of Figs. 7*a*, 7*b*, 7*c*, the amplitude x' is larger than the amplitude x whereas the amplitude y' is smaller than the amplitude y, the relation $x+y=x'+y'$ being satisfied. The amplitude of the partial tone c^0 of the perfect final sound spectrum according to Fig. 7*a* as composed after 0.3 second again of the sum of x' and z' which is substantially larger than the sum of x and z of the first differentiating case according to Fig. 6*a*. Thus it is seen that the additive building-up of the final tone in the principal stop 8′ according to Fig. 7*a* is already further advanced after 0.3 second and is complete to such a percentage that the human ear cannot perceive any difference from the 100% build-up which is accomplished after 0.4 second. Thus the aim given as an example is reached of completing already in 0.3 second the build-up of the partial tone c^0 in the perfect final sound spectrum notwithstanding the fixed building-up period of 0.4 second for the partial tone c^0 in the 8′ stop.

By the choice of the ratio $x:y$ at a given final amplitude in the additively composed perfect sound spectrum and at fixed building-up periods in the several tone positions according to Figs. 2*b* to 2*f* any desired differentiation of the time may be effected which is needed by a perfect partial tone until the building-up period in the perfect sound spectrum is completed. When the ratio $x:y$ is equal to 1:0, the building-up is completed in the perfect sound spectrum within 0.3 second with relation to the partial tone stops according to Figs. 6*c* and 6*b*. Between the values 0.3 second and 0.4 second any desired value may be realized.

To all other partial tones g^0 to e^2 according to Figs. 2*a*–2*f* the same rule applies in an analogous manner. The differentiation of the building-up period may be applied, if desired, also to the decay period t_2.

The differentiation according to the invention may be effected either by changing the dosing resistors, thus with respect to the partial tone c^0 by changing the resistors 74, 75 shown in Fig. 5, or by a corresponding proportioning of the limiting frequencies of the single filter section of the low pass members 67, 68. In the choice of one or the other of these two means it has to be taken into consideration that only the harmonic content of the partial tone stop may be changed but not of the fundamental being present in this stop. As shown in Fig. 2*b* the 8′ partial tone stop contains also the fundamental C of the perfect sound spectrum according to Fig. 2*a*. In changing the dosing resistor 74 the amplitude of the fundamental C in the partial tone stop according to Fig. 2*b* would be changed. In such case the amplitude of the partial tones in the 8′ stop has to be changed by means of the low pass members 68 by a corresponding choice of the limiting frequencies of the single filter sections of these members. For all other partial tone stops in which the fundamental C of the perfect sound spectrum is not present, for instance the stops shown in Figs. 2*c*–2*f*, the dosing resistors may be changed for differentiating the building-up periods.

I have described hereinafter a preferred embodiment of an electric organ. However, it should be understood that numerous changes, alterations, and substitutions of equivalents may be made in the embodiment shown in the drawings, my invention being defined by the accompanying claims.

I claim:

1. In an electronic organ having a plurality of multi-

position stops each provided with tone generator means; a plurality of parallel switches one for each stop position, a plurality of dosing resistors connected, respectively, to said switches, a plurality of R-C type formant filters connected, respectively, in series with said dosing resistors, a plurality of bus bars connecting the respective tone generator means to the associated formant filters; a plurality of time constant circuits connected, respectively, to said tone generator means for imparting to the individual tones within each stop position respective attack and decay periods; respective circuit means connected to said tone generator means of the upper stops only for ensuring pure tuning of said last-named tone generator means; said formant filters each comprising a plurality of serially connected resistances and a plurality of grounded capacitors connected in parallel with said resistances, a plurality of taps each connected to the junction between two adjacent ones of said resistances of a respective formant filter, additional resistances connected, respectively, to said taps, and additional switches connected, respectively, to said additional resistances for placing the same into or out of parallel connection with said dosing resistors, whereby formation of further tone colors with their transients in the various stop positions is rendered possible.

2. In an electronic organ or like electrical musical instrument having a plurality of multi-position stops each provided with tone generator means for providing harmonic-rich oscillations; means for synthetically imitating a sound of a pipe organ or like mechanical musical instrument, comprising a plurality of time constant controlling means connected, respectively, to said tone generator means for fixing the overall attack periods of said harmonic-rich oscillations, a plurality of formant filters each provided with low pass filter elements and connected, respectively, to said time constant controlling means for preforming said harmonic-rich oscillations, by means of subtractive tone formation, into a plurality of tone spectra each poor in harmonics, a plurality of dosing resistors connected to said formant filters, respectively, whereby the ratios between the amplitudes of corresponding upper tones of different ones of said tone spectra may be varied by selective adjustment of said dosing resistors and low pass filter elements without any change of said overall attack periods, and additional circuit means connected to said dosing resistors for synthesizing said tone spectra, by means of a time-staggered additive tone formation, into a final sound spectrum having transient characteristics exactly simulating the transient characteristics of the corresponding sound spectrum of said mechanical musical instrument.

3. In an electrical musical instrument designed for synthetically imitating a sound of a similar mechanical musical instrument and having a plurality of multi-position stops each provided with tone generator means for providing harmonic-rich oscillations; a plurality of time constant controlling means connected, respectively, to said tone generator means for fixing the overall attack periods of said harmonic-rich oscillations, a plurality of formant filters each provided with low pass filter elements and connected, respectively, to said time constant controlling means for preforming said harmonic-rich oscillations, by means of subtractive tone formation, into a plurality of tone spectra each poor in harmonics, and a plurality of dosing resistors connected to said formant filters, respectively, whereby the ratios between the amplitudes of corresponding upper tones of different ones of said tone spectra may be varied by selective adjustment of said dosing resistors and low pass filter elements without any change in said overall attack periods.

References Cited in the file of this patent

UNITED STATES PATENTS

1,530,498	Kendall	Mar. 24, 1925
2,403,090	Larson	July 2, 1946
2,403,664	Langer	July 9, 1946
2,410,883	Larsen et al.	Nov. 21, 1946
2,562,670	Koehl	July 31, 1951
2,562,908	Hanert	Aug. 7, 1951
2,682,616	Mork	June 29, 1954