

Sept. 15, 1931.

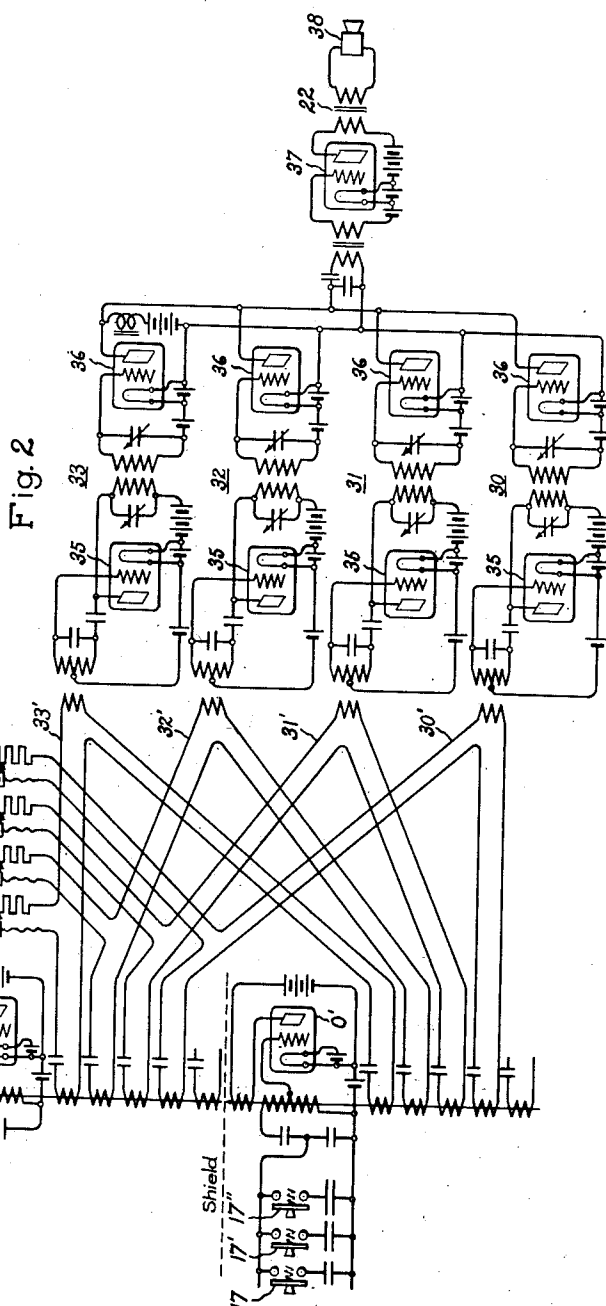
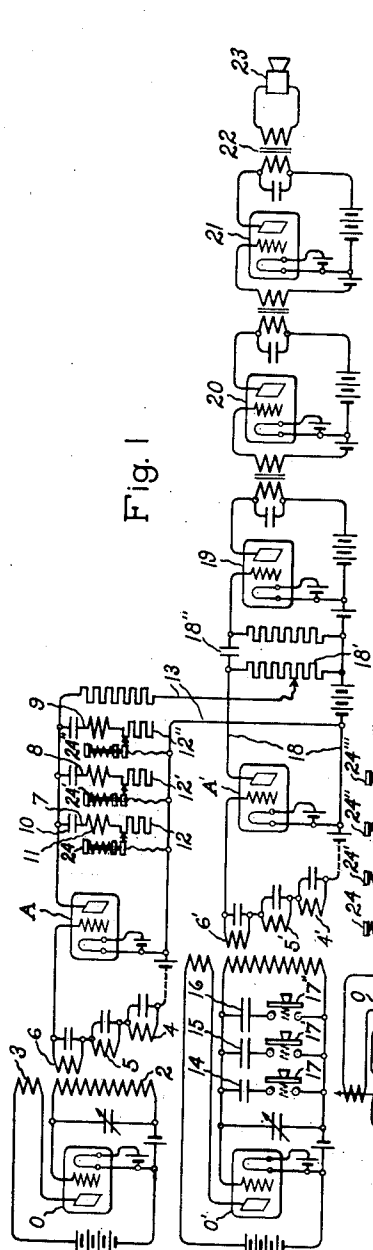
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MUSICAL INSTRUMENT

Filed May 22, 1930

2 Sheets-Sheer 1



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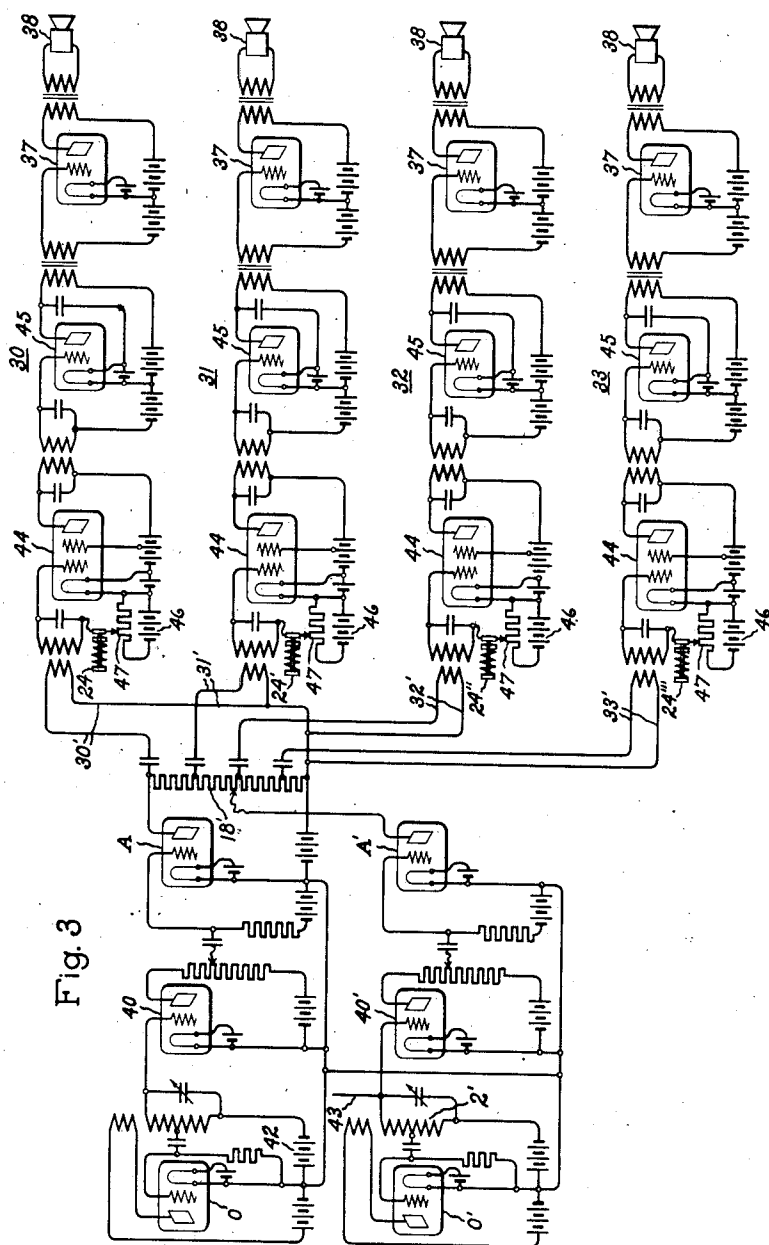
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UNITED STATES PATENT OFFICE

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MUSICAL INSTRUMENT

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My invention relates to means for electrically producing music and it has for one of its objects to provide a system capable of producing either pure musical tones, or tones having desired color or quality as determined by the presence of the proper harmonics or overtones having desired intensities.

A further purpose of the invention is to provide a system of the type indicated by means of which the range of tones produced may be sufficiently broad to constitute pleasing music and in which the tone quality may be more readily controlled over the entire range.

My invention relates still more particularly to the use in systems of the type indicated of a plurality of sources of radio frequency oscillations the output of which are combined to produce the desired tones. It has for a further object to provide means whereby the intensity and quality or color of the different tones may be varied by control of the circuits of the radio frequency sources. In this way very important advantages which will hereinafter appear may be had in the operation of the system.

The novel features which I believe to be characteristic of my invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings in which Figs. 1, 2 and 3 represent different embodiments of my invention.

Referring to Fig. 1 I have indicated at O an electron discharge oscillation generator by means of which radio frequency oscillations may be produced. This oscillation generator may be of any suitable type or construction, but is illustrated as one comprising a three element electron discharge device having a tuned circuit 2 connected between the grid and cathode, the inductance of which is inductively coupled with an inductance 3 which is connected between the anode and cathode. Coupled to this oscilla-

tory circuit are a plurality of additional tuned, or resonant, circuits 4, 5, 6, etc. which may be connected either in parallel or in series but which, for purposes of illustration, are represented as connected in series between the cathode and grid of an electron discharge amplifier A. One of these tuned circuits is tuned to the fundamental frequency of the oscillation generator O, and the others are tuned respectively to the different harmonics of this fundamental whereby the fundamental and each of its harmonics are accentuated and supplied to the grid of the electron discharge amplifier A.

Connected in parallel with the output circuit of the amplifier are a plurality of shunt paths comprising series tuned circuits 7, 8, 9, which are tuned respectively to the fundamental and the different harmonics of the fundamental which appear in the output of the amplifier A. These circuits each comprise a capacity, an inductance, and a variable resistance as indicated by the reference numerals 10, 11, and 12 applied to the circuit 7. As thus arranged with the variable resistance in any of these circuits reduced to a minimum or to zero, the tuned circuit comprises a substantial short circuit to oscillations of the frequency to which it is tuned. This frequency may be either the fundamental or any one of the harmonics. The effectiveness of each of these short-circuit paths and hence the intensity of oscillations of the corresponding frequency, whether it be the fundamental or any one, or more, of the harmonics thereof, which pass through the output circuit 13 may be controlled respectively by means of the resistance 12, 12', 12'' of the corresponding circuit 7, 8, 9.

In order to facilitate control of the resistances 12, 12', 12'' each of the variable contacts thereof are shown, for purposes of illustration, as connected to a corresponding spring-biased key 24, 24', 24''. These keys may be normally biased upwardly by the associated springs and adapted to be operated downwardly by the fingers. As shown in the drawings the upward position is that in which the corresponding resistance is a

minimum and the circuit comprises a substantial short circuit to oscillations of the corresponding frequency. These keys 24, 24', 24'' may be arranged in any suitable way to permit easy manipulation by the operator.

At O' I have shown a second oscillation generator which may be of a construction similar to that of oscillation generator O, but which includes in parallel with the tuned circuit thereof a plurality of condensers 14, 15, 16, the connection of each of these condensers in parallel with the tuned circuit being controlled respectively by suitable switches 17, 17', 17'' which may, for example, be of the push button type and biased to the open position. Each of these condensers is of different capacity. Thus by closing the switches 17, 17', 17'' the frequency of oscillations produced may be varied in accordance with the different tones to be produced. These controls for the generator O' may be arranged in proximity to the keys 24, 24', 24'' in any suitable way to permit easy manipulation by the operator. Preferably they may be so arranged that the keys 24, 24', 24'' may be manipulated by the fingers of one hand and the switches 17, 17', 17'' by the fingers of the other hand. Coupled to the inductance of the oscillatory circuit are additional oscillatory, or resonant, circuits 4', 5', 6' which similarly with oscillatory circuits 4, 5, 6 are tuned respectively to the fundamental frequency and the different harmonics produced by the generator O'. Thus this fundamental and the harmonics are accentuated and supplied to the grid of the amplifier A'.

Connected in parallel with the output circuit 18 of the amplifier A' is a high resistance potentiometer 18' to the lower portion of which is connected the output circuit 13 of the oscillating system O. The potential upon this resistance is supplied through a grid condenser 18'' to an electron discharge detector 19. Due to the detecting action of this discharge device the current in the output circuit thereof will have, among others, a frequency corresponding to the difference in frequency between the fundamentals of the oscillation generators O and O' and other oscillations corresponding to the difference in frequency between the various harmonics thereof. That is, there will appear in the output circuit of detector 19 oscillations having a frequency corresponding to the difference in frequency, or beat frequency, between the fundamentals produced by the two generators O and O', and there will also appear each of the different harmonics of this difference or beat frequency, each of these harmonics corresponding, of course, to the difference in frequency between the respective harmonics of the generators O and O'.

As will now be apparent the intensity of the fundamental beat frequency and that of each of its harmonics may be controlled as desired by operation of the keys 24, 24', 24''. These oscillations are amplified in the audio amplifiers 20 and 21, and are then supplied through a transformer 22 to a loud speaker 23 whereby they are converted into sound having the desired tone and tone quality as determined by the fundamentals and various harmonics supplied thereto.

Thus, for example, in the operation of the system the oscillation generator O will be arranged to produce oscillations having a certain fundamental frequency which, for example, may be considered as 100 kilocycles. The circuit 4 will thus be tuned to this frequency. Present also in the output of the oscillation generator are both even and odd harmonics having frequencies of 200 kilocycles, 300 kilocycles, 400 kilocycles, etc. The circuit 5 will thus be tuned to the frequency 200 kilocycles and the circuit 6 to the frequency 300 kilocycles. If desired more of these circuits may be included as indicated by the dotted line connection of the circuit in the cathode of discharge device A. The degree of coupling between the tuned circuits 2 and each of the tuned circuits 4, 5, 6 may be adjusted in accordance with the frequency as indicated by the spacing in the drawing between the respective circuits 4, 5, 6 and the circuit 2. The circuits 7, 8, and 9 will likewise be tuned to resonance respectively at 100 kilocycles, 200 kilocycles, 300 kilocycles, etc., there being as many of these circuits as there are harmonics which it is desired to control.

The frequency of generator O' with all of the keys 17, 17', 17'' open may then be adjusted to the same frequency as the oscillator O thereby to produce a zero beat between the two generators.

Thus, let us assume, for example, that the fundamental frequency in the output circuit of the system should vary over a range of ten thousand cycles or ten per cent of the normal frequency of the generator O'. The frequency of this generator will vary upon closing of the different keys 17, 17', 17'' from 100,000 cycles to 90,000 cycles. The same percentage variation will also occur in each of the different harmonics of this fundamental. The circuit 4' will thus be tuned broadly to respond to frequencies ranging from 90,000 to 100,000 cycles, the circuit 5' to frequencies 180,000 to 200,000 cycles, the circuit 6' to frequencies from 270,000 to 300,000 cycles, etc.

Thus with a certain key closed corresponding to a certain pitch a corresponding audio frequency plus each of its harmonics will be produced in the output circuit, the intensity of the fundamental and each of the harmonics being controlled respectively by

the keys 24, 24', 24'' etc. To produce either a lower or higher note, or pitch, the operated key is released and another pressed corresponding to the new note.

5 While I have particularly mentioned the use of 100,000 cycles as the frequency of the system O and the normal frequency of the system O', it will of course be understood that I do not wish to be limited thereto
10 since either lower or higher frequencies may be used. I contemplate, in accordance with my invention, the use of frequencies sufficiently high to permit the entire tone range to be produced without adjustment of the
15 circuits 4', 5', 6', etc., that is, the percentage change in frequency which occurs in producing the various tones should be sufficiently small to permit proper operation over the entire tone range without adjustment of
20 these circuits. Further these frequencies should be sufficiently high to prevent overlapping of the range of variations of the fundamental, for example, with that of the second harmonic, or that of any harmonic
25 with a next higher harmonic. That is, the highest fundamental frequency produced by the system should be lower than the lowest second harmonic frequency, and similarly with respect to the second and third har-
30 monics, the third and fourth harmonics and so on throughout the audio range. In this way throughout the range of tones produced the intensity of the fundamental tone and that of each of the over-tones simultane-
35 ously produced, that is, each of the different components of the sound output, may be separately and independently controlled by the corresponding key 24, 24', 24'', and oper-
40 ation of none of these keys will affect the intensity of other than the fundamental or respective harmonic.

In the operation of musical instruments the degree of control over the tone quality should be as flexible as the control of the
45 fundamental tone and the sound volume of output. Pure tones become monotonous unless mixed with more complex tones and the shading or quality of the tones controlled in accordance with the skill of the artist in
50 interpreting the soul of the music. In the operation of applicant's system as now explained, it will be seen that either pure or complex tones may be produced and the shading and color of the different tones controlled over any suitable range as desired by
55 the artist, there being no inherent limitation, as in most mechanical musical instruments, in the relation between the strength of the various harmonics and the fundamental. It is thought that the human voice or speech
60 may be closely approximated by the system as herein described and that one who has lost the power of speech may be enabled artificially to talk.

65 It will be noticed in the system as shown

in Fig. 1 that the channel 13 is connected across only a portion of the potentiometer 18'. In this way the voltage of generator O which is impressed upon the grid of the detector 19 is maintained materially smaller
70 than that from generator O'. The purpose of this is to prevent the production of undesired harmonics and distortion resulting from operating the device 19 upon the curved portion of its characteristic. If de-
75 sired the generator O may be of smaller capacity than that of generator O'.

In Fig. 2 I have shown a further embodiment of my invention which is similar to that shown in Fig. 1, with the exception
80 that different channels are employed for the amplification of the different harmonics. Thus, for example, the channel 30 may be employed to amplify the fundamental fre-
85 quency produced by the oscillation generators O and O'; the channel 31 to amplify the second harmonic, the channel 32 the third harmonic, channel 33 the fourth harmonic, etc. As many of these channels as desired
90 may be employed. Each of these channels includes a radio frequency amplifier 35 having an input circuit which is coupled by means of a respective circuit 30', 31', 32',
95 33' to the output of each of the oscillation generators O and O', these coupling circuits of course being tuned to the corresponding frequency and including resistance 12, 12',
100 12'', etc., which may be controlled by keys 24, 24', 24'', etc., as explained in connection with Fig. 1. Due to the high frequencies at which the high frequency generators oper-
105 ate the desired tones may be controlled by operation of the keys 17, 17', 17'' and without any adjustment of the coupling circuits 30', 31', etc., or of the tuned circuits of the amplifier 35. Each channel also includes a
110 detector 36 for producing a beat note between the waves supplied thereto. Thus, the detector 36 in channel 30 will produce a beat frequency between the two fundamen-
115 tal waves supplied thereto. Detector 36 in channel 31 will produce a beat frequency between the second harmonics of these fundamental waves. The detector 36 of the channel 32 will produce a beat frequency be-
120 tween the third harmonics of these fundamental waves, etc. The output circuit of each of these detectors are connected together and are supplied to the input circuit of an audio amplifier 37 where they are
125 amplified and supplied to a loud speaker 38.

It will thus be seen that this arrangement has an individual channel which is pro-
130 vided for the purpose of amplification and detection of the fundamental, and each of the different harmonics. If desired, these individual channels may extend to separate sound producing devices or loud speakers. This arrangement is shown in Fig. 3 in
135 which the channels 30, 31, 32, 33 correspond

to those shown in Fig. 2, but each of which includes in its output circuit an audio amplifier 37 and an individual loud speaker 38.

The arrangement here disclosed is further modified in that the output from the oscillation generator O is supplied to an electron discharge device 40 having a suitable negative bias impressed upon its grid by means of a bias source 42 thereby to cause this tube to operate upon the curved portion of its characteristic. As thus adjusted the tube operates not only to amplify the fundamental wave supplied from the system 1 but to produce harmonics thereof in a manner well understood in the art. This fundamental and the harmonics are then supplied to a radio frequency amplifier A having a potentiometer 18' connected in its output circuit. In the same way the output from the generator O' is applied to harmonic generator 40', the output of which is amplified by the device A' and supplied to a portion of the potentiometer 18'. The input to each of the channels 30, 31, 32, 33 are then connected respectively through tuned circuits 30', 31', 32', 33' connected across suitable portions of the potentiometer 18' as shown whereby the two fundamental waves and the harmonics thereof are supplied to respective channels. Thus the circuit 30' may be tuned to the fundamental waves, the circuit 31' to the second harmonic thereof, the circuit 32' to the third harmonic, and the circuit 33' to the fourth harmonic, etc. As previously stated, due to the high frequencies employed, these channels require no variation in tuning for the different tones. In this case the frequency of the oscillation generator O' is controlled by means of a vertical conducting electrode 43, which is connected to the tuned circuit 2' of the oscillation generator O'. Thus the frequency of this generator may be varied by variation of the hand of the operator with respect to the electrode 43 much in the manner described in Patent No. 1,661,058, of L. S. Theremin, issued February 28, 1928.

Each of the channels 30, 31, 32, 33 etc. includes a radio frequency amplifier 44, and a detector 45, by means of which the corresponding frequencies are produced in the audio amplifier 37. Each of the amplifiers 44 has a negative bias impressed upon the grid thereof by means of a bias battery 46 and potentiometer 47. The connection of the grid of this potentiometer may be controlled by keys corresponding to keys 24, 24', 24'' of Fig. 1, thereby to control the amplification characteristic of the device 44 and the intensity of the oscillations supplied to the corresponding loud speaker 38. Thus by the different keys 24 the intensity of the fundamental and the various harmonics may be readily controlled thereby

to produce the tone color desired by the operator.

While I have shown a particular embodiment of my invention it will of course be understood that I do not wish to be limited thereto since many modifications, both in the circuit arrangement and in the instrumentalities employed, may be made, and I therefore contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The combination, in a system for electrically producing music of an oscillator adapted to produce radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, a second oscillator adapted to produce radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, the fundamental of the second oscillator differing in frequency from the fundamental of the first oscillator by an amount corresponding to a desired tone, means for controlling the frequency of one of said oscillators thereby to vary the tone produced, means for producing beat frequencies between oscillations from said oscillators, and means for independently controlling the intensity of the fundamental and of each of said harmonics produced by one of said oscillators thereby to control the quality of the tone produced.

2. The combination, in a system for electrically producing music of a source of radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, a second source of radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, the fundamental of the second source differing in frequency from the fundamental of the first source by an amount corresponding to a desired tone, means for producing beat frequencies between oscillations from said sources, and means for varying the fundamental frequency produced by one of said sources to produce different tones and for controlling the intensity of oscillations produced by the other source to vary the quality of said tones.

3. The combination, in a system for electrically producing music of a source of radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, a second source of radio frequency oscillations having frequencies corresponding to a fundamental and certain of the harmonics thereof, the fundamental of the second source differing in frequency from the fundamental of the first

source by an amount corresponding to a desired tone, means for producing beat frequencies between oscillations from said sources, and means for varying the fundamental frequency produced by one of said sources to produce different tones and independently varying the intensity of the fundamental and each of the harmonics produced by the other source to control the quality of said tone.

4. The combination, in a system for electrically producing music of a source of radio frequency oscillations having a certain fundamental frequency and harmonic frequencies thereof, said source including a plurality of circuits each of said circuits being tuned respectively to a different one of said frequencies, a second source of radio frequency oscillations having a certain fundamental frequency and harmonics thereof, means for producing beat frequencies between the output of said sources, the frequency of said fundamentals being such that frequencies corresponding to a desired musical tone and certain overtones thereof are produced by said last means, means for varying the fundamental frequency of said first source, said fundamental frequencies being such that a substantial range of musical tones of desired intensity is produced in response to variations in said fundamental without altering the tuning of said tuned circuits.

5. The combination, in a system for electrically producing music of a pair of sources of oscillations, each of said sources being adapted to produce oscillations having a fundamental frequency and certain harmonics thereof, a detector connected to be supplied with oscillations from both of said sources, and a sound producing device connected in the output of said detector whereby musical tones having a plurality of components comprising a fundamental tone and certain overtones thereof are produced by said sound producing device, means for varying the fundamental frequency of one of said sources thereby to vary the tone and overtones produced over a desired range of musical frequencies, means including a tuned circuit for separately controlling the intensity of each of said components, said sources being adapted to produce fundamental frequencies sufficiently high to permit the entire tone range to be produced and the intensity of each of said components to be determined over the entire range by a single one of said tuned circuits.

6. The combination, in a system for electrically producing music of a pair of sources of oscillations, each of said sources being adapted to produce oscillations having a fundamental frequency and certain harmonics thereof, a detector connected to be supplied with oscillations from both of said sources, and a sound producing device con-

nected to the output of said detector whereby musical tones having a plurality of components comprising a fundamental tone and certain overtones thereof are produced by said sound producing device, individual means for controlling the intensity of each of said components, means for varying the fundamental frequency of one of said sources thereby to vary the tone and overtones produced over a desired range of musical frequencies, said sources being adapted to produce fundamental frequencies sufficiently high to permit the entire tone range to be produced without overlapping of the range of variations of the different components.

7. The combination, in a system for electrically producing music of a pair of sources of oscillations, each of said sources being adapted to produce oscillations having a fundamental frequency and certain harmonics thereof, a detector connected to be supplied with oscillations from both of said sources, and a sound producing device connected to the output of said detector whereby musical tones having a plurality of components comprising a fundamental tone and certain overtones thereof are produced by said sound producing device, means for varying the fundamental frequency of one of said sources over a desired range of musical frequencies, means comprising a plurality of tuned circuits connected in shunt with the output from the other of said sources for controlling the intensity of said components, the different tuned circuits being tuned respectively to the different frequencies produced by said source, and the frequencies of said sources being sufficiently high to prevent overlapping of the range of variations of the different components whereby the intensity of each component is controlled over the entire range of variations by the respective tuned circuit.

In witness whereof, I have hereunto set my hand this seventeenth day of April, 1930.

WENDELL L. CARLSON.