

Feb. 22, 1944.

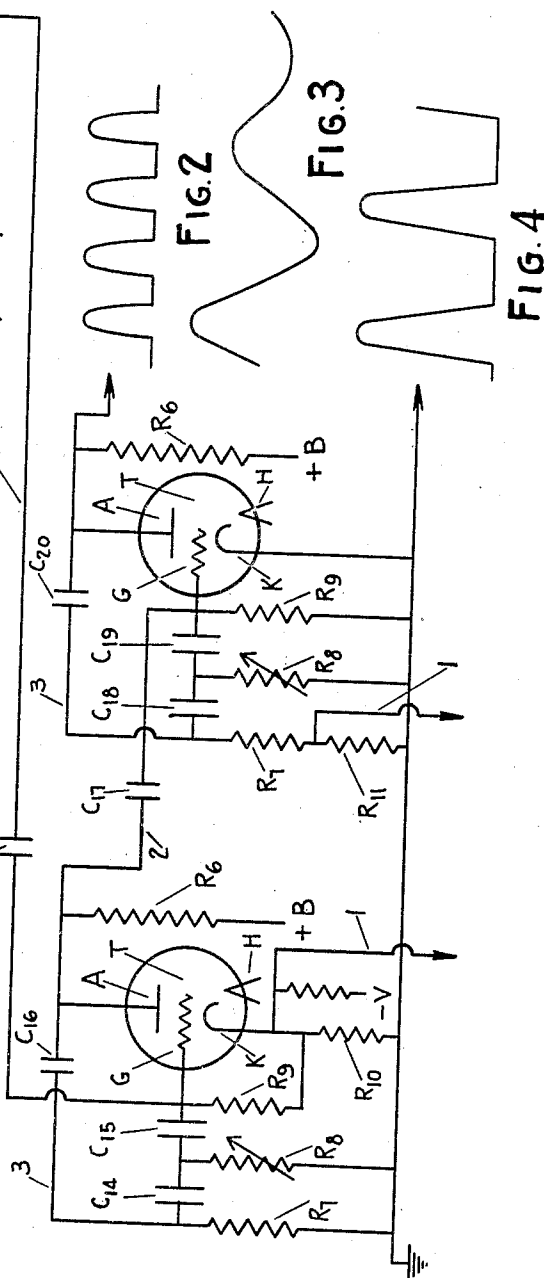
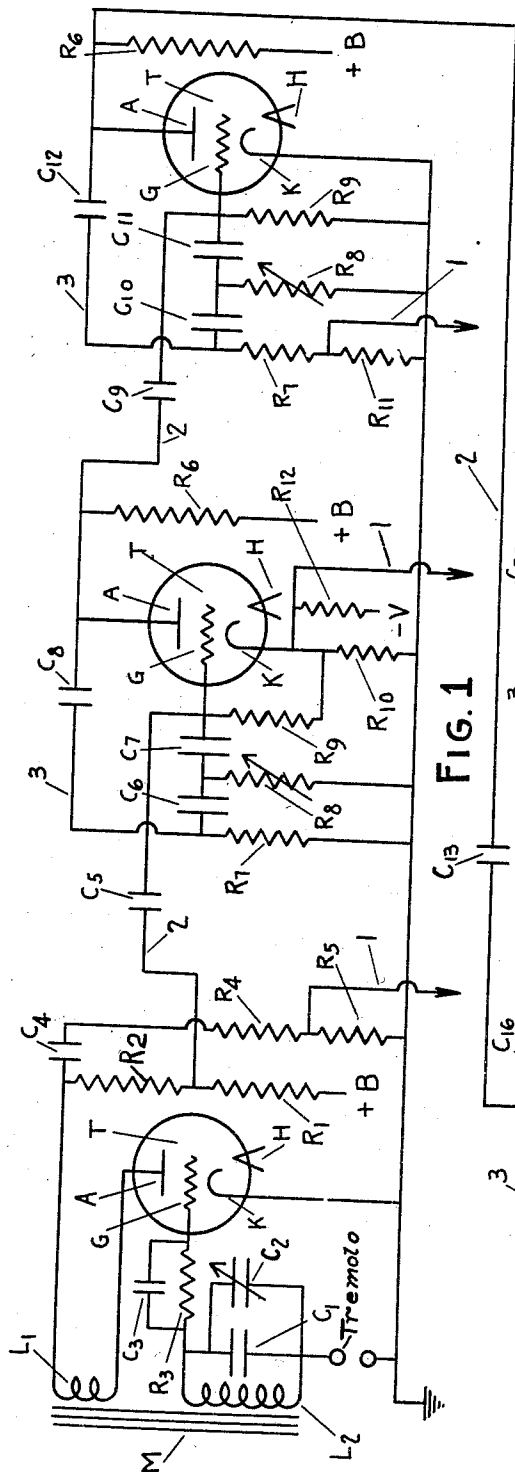
W. E. KOCK

2,342,286

OSCILLATION GENERATING SYSTEM

Filed Oct. 1, 1941

2 Sheets-Sheet 1



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OSCILLATION GENERATING SYSTEM

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2 Sheets-Sheet 2

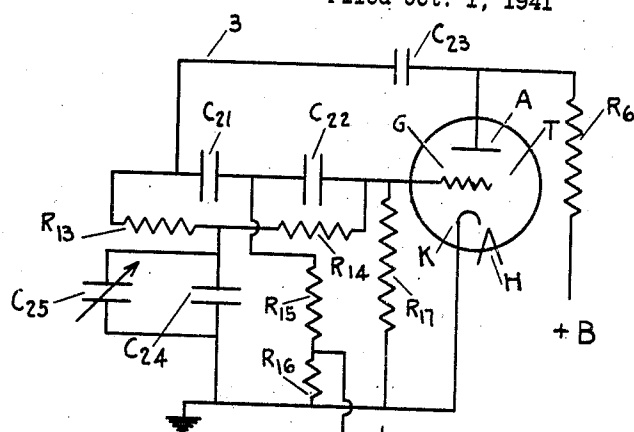


FIG. 5

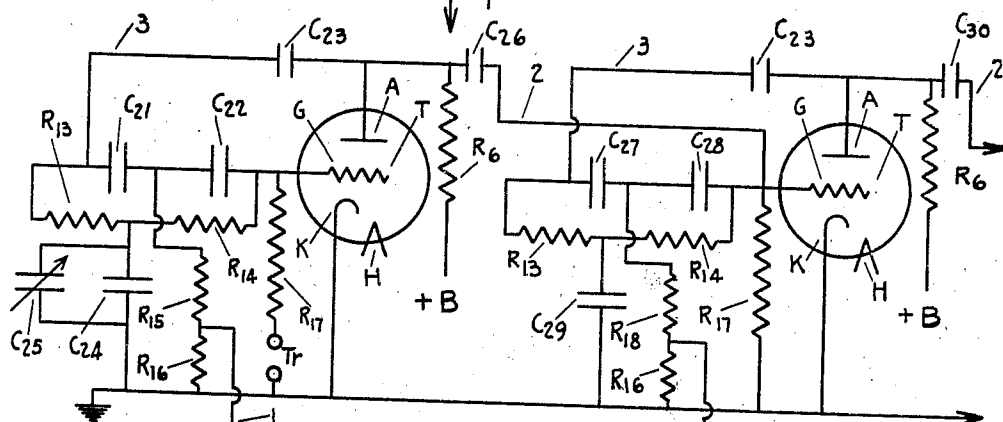


FIG. 6

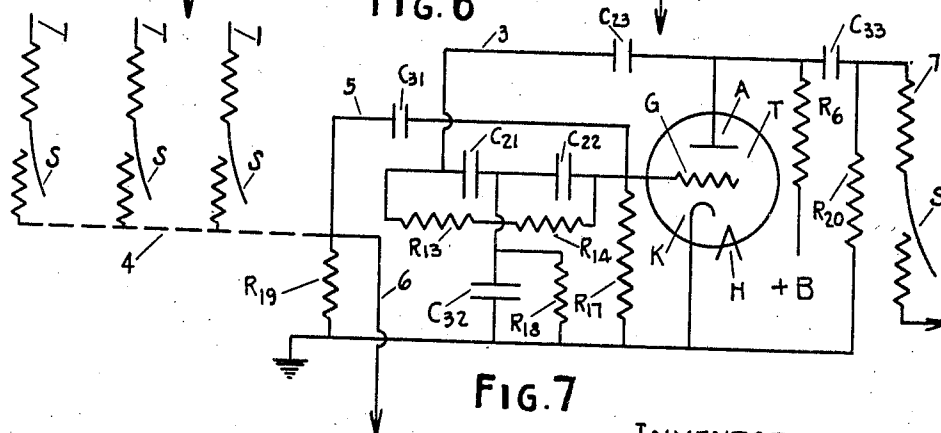


FIG. 7

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2,342,286

OSCILLATION GENERATING SYSTEM

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Application October 1, 1941, Serial No. 413,199

6 Claims. (Cl. 250—36)

My invention relates to the production of electric oscillations. It is particularly useful in the electrical production of music, and accordingly will be set forth in the present disclosure in the form of an assembly for generating audio frequency oscillations for the various notes and tone color systems of a polyphonic electrical musical instrument.

As a general object the invention contemplates an oscillation generating assembly having the fundamental advantages of low cost of construction, stability and durability, in which oscillations are generated according to tone color requirements set forth in my United States Patent No. 2,233,948 issued March 4, 1941, for improvements in Electrical organs. That is, it is an object of the invention to provide an economical oscillation generating assembly in which oscillation waveforms are complex, i. e., have considerable harmonic content, and are essentially similar for the various oscillation frequencies of the instrument, octavely assigned oscillations are maintained in exact octave relationship, and octavely related oscillations as derived from the assembly are substantially in phase.

Briefly, I accomplish the above by providing a plurality of cascades of electric oscillation generators known as phase-shift oscillators, one such cascade being provided for each of the series of octavely related notes in a multioctave musical instrument. At the head of each cascade I provide a suitable stabilized or master oscillator having the frequency of the top note of the corresponding octave series. This master generator in turn controls a phase-shift oscillator suitably arranged so that the latter operates under the control at an exact octave below the master, thereby corresponding to the second note of the series; the oscillator thus controlled then controls a second phase-shift oscillator so that the second controlled oscillator operates exactly an octave below the first, corresponding to the third note of the series; and so on throughout the series, as many members being provided for the various cascades as necessary to attain the desired note compass of the instrument.

With reference to the term "phase-shift oscillator" the type of oscillation generator I employ may be thought of in principle as a single stage vacuum tube resistance-coupled amplifier having its output circuit coupled to its input circuit through a suitable phase shifting network, so that the device becomes a self-oscillator of the regenerative type (as distinguished from a relaxation oscillator). It is known that the grid

input and plate circuit output voltages of a single tube resistance-coupled amplifier are normally out-of-phase, and a simple coupling of the two circuits will therefore not produce regenerative action. If, however, a network effecting a phase change of the order of 180° for oscillations passing through it is employed for the coupling, regenerative action is obtained and the device becomes the oscillator indicated, providing the tube has sufficient voltage gain to overcome the attenuation in the network. It happens that suitable tubes for the purpose are readily available among the tubes now employed in radio receivers and I shall later indicate a particular type of tube I prefer to employ.

As to the phase shifting network I use a type of network comprising capacities in a series arrangement shunted by resistances. This has the advantage that the parts employed are relatively low in cost. At frequencies above the designed frequency of the oscillator the reactances of the capacities (which produce the phase shift) become negligible as compared with the resistances so that phase shift does not take place, whereas at frequencies below the designed frequency the excessive reactances of the capacities result in either too much phase shift to produce oscillation and/or the capacity reactances produce too much voltage attenuation for sustained oscillation to result. Consequently the device oscillates at a definite frequency or within a small range of frequencies. (I shall later show that a particular modification of a phase-oscillator can be provided having sufficient frequency stability so that it is suitable as a master oscillator in an electrical musical instrument.)

I have found in employing phase-shift oscillators in cascades such as described below that they are particularly susceptible of being raised in frequency under the influence of periodic electric pulses of higher frequency, so that under the control of the pulses they operate at an exact subharmonic of the pulse frequency. In the instance of a musical instrument the suboctave is an especially desired subharmonic and under this condition I have found it advantageous to set a phase-shift oscillator about six semitones below the frequency to which it is to be raised by control. For example, if the oscillator is to operate at the C note of 1046.5 C. P. S. (cycles per second) under the control of pulses from the C note at 2093 C. P. S. the oscillator should oscillate unattended at about 740 C. P. S. (about F# below the 1046.5 C). This particular feature has been previously discussed in the aforementioned Pat-

ent No. 2,233,948 and in United States Patent No. 2,230,429 issued February 4, 1941, to John F. Jordan and myself as joint patentees for Means for generating electric oscillations.

I have furthermore found that under suitable arrangement phase-shift oscillators can be made incapable of sustained oscillations but that under this suitable non-oscillatory condition will operate very satisfactorily as frequency dividers when pulsed as aforesaid, just as when they are self-oscillatory. The same relations, as to frequency raising and the like as discussed just above, hold for this non-oscillatory condition. The use of the devices as non-self-oscillatory frequency dividers is especially advantageous in the electrical production of music, since the failure of a device results only in silence from the notes corresponding to the elements below it in a cascade series, rather than the production of off-pitch tones. The advantage of this has been previously recognized, in the aforementioned Patent No. 2,230,429 and in United States Patent No. 2,185,635 issued January 2, 1940, to John F. Jordan and myself as joint patentees for Frequency dividers.

As to a further use for non-oscillatory phase-shift devices I have also found that they may be advantageously employed in the tone color circuits of electrical musical instruments, as filters for accentuating and/or attenuating the harmonics of complex oscillations within predetermined frequency bands to form particular tone colors.

A detailed manner in which the above is attained and the attainment of those further objects of the invention which will be indicated hereinafter or will occur to those skilled in the art on reading this specification, will now be described specifically, reference being made to the accompanying drawings forming a part hereof, wherein:

Figure 1 is a wiring diagram of a master oscillation generator and a cascade of oscillation generating devices for producing octavely related oscillations;

Figure 2 illustrates the waveform of pulses such as are used for frequency control in the cascade of Figure 1;

Figure 3 represents the waveform of oscillations generated by a device such as those in the cascade of Figure 1, when not operated upon by controlling pulses; whereas

Figure 4 illustrates the waveform of oscillations derived from such a device when acted upon by controlling pulses;

Figure 5 is a wiring diagram of a modified form of oscillation generating device;

Figure 6 illustrates the use of devices such as that of Figure 5 as a master oscillation generator and as an associated frequency divider; and

Figure 7 illustrates the use of a device such as that of Figure 5 as a means for modifying oscillations for tone color purposes.

Throughout the various figures of the drawings I have illustrated ground by the conventional symbol, and unless otherwise set forth in this description ground will be used as a return for circuits and as a common or reference potential. Thus for example the sources of direct current potential $+B$ and $-V$ indicated in the drawings are referred to ground for their return terminals. These sources $+B$ and $-V$ may of course be obtained by suitable rectification and filtering of commercial alternating current.

With detailed reference to Figure 1, I have shown a cascade of phase-shift devices as above

outlined, for the C notes of an electrical musical instrument, it being understood that a corresponding cascade, except for values of parts, is provided for each of the remaining groups of octavely related notes in the instrument. As illustrated the devices of Figure 1 contain respective vacuum tubes T, each tube having an anode A, a thermionic cathode K, and a control grid G between these two elements. A heater H, which may be energized by alternating current, is provided for each cathode K.

At the upper left of Figure 1 is shown a master oscillator for the cascade, of a well-known regenerative vacuum tube type. As illustrated the anode-to-cathode circuit of its tube T contains the source of anode potential $+B$, resistances R_1 and R_2 connected in series thereto, and the inductance L_1 connected to R_2 and to the anode A. Regeneratively coupled to the anode-to-cathode circuit is the grid-to-cathode or frequency control circuit. In this control circuit a tuned tank impedance comprising an inductance L_2 and a condenser C_1 in parallel is connected between the grid G and the cathode K. A small trimmer condenser C_2 is in parallel with C_1 for critical tuning of the oscillator. The coupling between the two circuits is, as shown, between the inductances L_1 and L_2 which have a common ferromagnetic core M as illustrated. Also contained in the grid-to-cathode circuit are a condenser C_3 and a resistance R_3 in parallel. These serve to provide grid bias for the oscillator and to insure that it starts oscillating when the system is "turned on," by setting up a transient potential of the grid under initial condition.

Further contained in the grid-to-cathode circuit is a source of sub-audio alternating voltage (marked "Tremolo"). This source is employed to provide a frequency tremolo or pitch vibrato in a musical instrument using the present oscillation generating system and may take the form of the tremolo set forth in the aforementioned Patent No. 2,230,429. As in the structure described in the patent the tremolo source (marked "Tremolo") varies the grid potentials of the present master oscillators, to vary slightly their frequencies and through them the frequencies of the members of the attendant cascades, at a sub-audio rate of about 6 C. P. S. to provide the desired pitch vibrato.

As to the main operating characteristics of the master oscillator the tank impedance L_2 , C_1 , C_2 is tuned to a frequency of 2093 C. P. S., corresponding to a high C note in the equitempered musical scale based upon $A=440$ C. P. S., through preselections of the values of parts for the impedance and by vernier setting of the trimmer condenser C_2 connected therewith. The oscillator thus operates at the desired frequency, the oscillations being sustained through the adequate coupling between its two electrode circuits.

As employed herein the master oscillator is used both to produce oscillations for tone production for the corresponding note and as a source of control pulsations for the attendant cascade of phase-shift devices. For deriving oscillations for tone production at the high C note of 2093 C. P. S. a series arrangement of a condenser C_4 , a resistance R_4 and a resistance R_5 is connected to the anode-to-cathode circuit of the oscillator, as illustrated one terminal of the condenser C_4 being connected to the circuit between the resistance R_2 and the inductance L_1 and one end of the resistance R_5 being connected to ground. Tone productive os-

oscillations are derived through the lead 1 connected to the junction point of the resistances R_4 and R_5 . The oscillations as thus secured are of complex character, their waveform being similar to that shown in Figure 2. For controlling the attendant cascade of phase-shift devices another lead 2 is employed, connected to the anode-to-cathode circuit of the master oscillator at the junction point of the resistances R_1 and R_2 . The control pulses appearing in this lead 2, likewise having the frequency of 2093 C. P. S., are also of the waveform shown in Figure 2. The other end of lead 2 is connected to the grid G of the tube T of the first phase-shift device of the adjoining cascade, a condenser C_5 being interposed in the lead.

I have set forth in the above that phase-shift devices may be employed in this invention either in the oscillatory or non-self-oscillatory state, and that in respect to a musical instrument the use of non-oscillatory frequency dividers is particularly advantageous. Consequently in the following I shall describe the devices as being incapable of self-sustained oscillations and the values of parts given therefor will accordingly relate to this condition. However by appropriate change of these values the devices can if desired be made self-oscillatory.

Taking up the first phase-shift device of the cascade, adjoining the master oscillator, the member has an anode-to-cathode circuit containing the source of anode potential $+B$ and a resistance R_6 connecting the source and the anode A, and a grid-to-cathode circuit containing a phase shifting network comprising the condensers C_6 and C_7 and the resistances R_7 , R_8 , and R_9 . As illustrated the condensers C_6 and C_7 of the network are connected in series, with the condenser C_7 connected to the grid G, whereas the resistance R_7 is connected to condenser C_6 , the resistance R_8 is connected to the junction of the two condensers, and the resistance R_9 is connected directly to the grid. The other ends of the three resistances connect to ground. A coupling lead 3 is connected from the anode A to the junction point of condenser C_6 and resistance R_7 of the network, a condenser C_8 being placed in the lead.

The phase-shift device as set forth is incapable of self-sustained oscillations, being so arranged that under shock from a single external pulse it will produce a single train of damped oscillations. This train of damped oscillations is illustrated in Figure 3. The frequency of the oscillations in the train is arranged to be about 740 C. P. S. (about six semitones below the 1046.5 C note) through selections of values for various parts and by setting the resistance R_8 which is adjustable as illustrated.

As was above outlined a phase-shift device may be raised in frequency by periodic pulses of higher frequency so as to operate continuously as a frequency divider at an exact subharmonic of the pulse frequency. Thus under the influence of the control pulses at 2093 C. P. S. from the master oscillator, pulsing the grid G of the first phase-shift device of the cascade through the lead 2, the device operates at an exact octave below the master oscillator, i. e., at the 1046.5 C. P. S. C note, and oscillations for tone productive purposes may be derived from the device at that frequency. For this purpose the cathode K is connected to ground through a resistance R_{10} , the resistance R_9 being grounded through R_{10} , and a tone productive lead 1 is connected to the junction

point of the cathode K and the resistance R_{10} .

The waveform of the oscillations derived from the phase-shift device for tone production is illustrated in Figure 4. It will be noted that these oscillations are of complex character and similar to those derived from the master oscillator as shown in Figure 2. It will be further noted that these oscillations derived from the device when continuously operated by influence of external pulses differ considerably in waveform from the damped oscillations of the device when shocked by a single pulse, the damped oscillations being substantially sinusoidal as shown. I believe that this is caused by cancellation of the lower half of the sinusoidal oscillations by alternate pulses of the incoming series of controlling pulsations.

In a similar manner the first phase-shift device of the cascade controls the second so that the latter operates at the 523.25 C. P. S. C note two octaves below the master oscillator, the second controls the third to three octaves below the master, and so on throughout the cascade, Figure 4 representing the waveform of the tone productive oscillations from the various members. While I have shown only four dividers in the cascade additional members can be added as indicated by the arrows pointing toward the right from the lowest frequency device illustrated in Figure 1.

As will be noted the various control leads 2 connecting adjacent phase-shift devices of the cascade are each connected from the anode A of a preceding device to the grid G of a succeeding one. In this disclosure various parts have similar functions and values and wherever this occurs I have endeavored to denote the parts by similar indicia. Thus the various resistances R_7 , R_8 and R_9 are uniform throughout a cascade with consequent simplicity and economy, the designed frequencies of the phase-shift devices being arranged through the use of condensers of various values in the various phase shifting networks of the devices. Accordingly these condensers are indicated by C_6 and C_7 , C_{10} and C_{11} , C_{14} and C_{15} , and C_{18} and C_{19} for the respective cascade members. Likewise the condensers interposed in the various leads 2 connecting adjacent devices are indicated by C_9 , C_{13} and C_{17} , and the condensers illustrated in the various feedback leads 3 are denoted by C_8 , C_{12} , C_{16} and C_{20} .

In this way oscillations are obtained for tone productive purposes in which oscillation waveforms are similar and octave relationships are exact. A remaining problem is to provide substantially in-phase relationships between octave-related oscillations. I have found in this regard that if in the cascade system described oscillations are derived from the various members at corresponding points, such oscillations are substantially out-of-phase, as between the master oscillator and the first driven member and as between adjacent driven members. However, I obtain the desired result by deriving oscillations from the master oscillator and the first driven member as has already been described and I also derive oscillations from the third, fifth, etc., driven members as from the first. As to the second, fourth, etc., driven members, I interpose respective resistances R_{11} between their resistances R_7 and ground and I connect leads 1 for tone production to the junction points of these resistances R_7 and R_{11} . In this way all the oscillations from a cascade are substantially in phase.

As aforescribed; tone productive oscillations

are derived from the first, third, etc., phase-shift devices across resistances R_{10} connected between the respective cathodes of these members and ground. Now it will be noted that the voltage appearing across each of these resistances comprises not only the oscillation voltage but also a considerable D. C. voltage caused by the average anode-to-cathode current of the corresponding tube flowing through the resistance, and unless otherwise counteracted this D. C. voltage produces a loud "click" in an ensuing tone when the corresponding device is connected in playing to the tone color and reproducing systems of a musical instrument. However I remove this undesirable effect by neutralizing this D. C. voltage, by connecting a source of negative potential $-V$ to the cathodes of the first, third, etc., phase-shift devices, through respective resistances R_{12} as illustrated.

In Figure 5 is shown a modified form of phase-shift oscillator having considerable frequency stability. In this modification the phase shifting network comprises an arrangement of two condensers C_{21} and C_{22} in series shunted by two resistances R_{13} and R_{14} in series, one end of this combination, the junction of C_{22} and R_{14} , being connected to the grid G of the oscillator tube T and the other end to the feedback lead 3. As before the lead 3 is connected to the anode A of the tube, with a condenser C_{23} interposed in the lead. Shunted between the junction point of the resistances R_{13} , R_{14} and ground is a condenser C_{24} , and shunted between the junction point of the condensers C_{21} , C_{22} and ground is a resistance R_{15} . For deriving tone productive oscillations from the device the resistance R_{15} connects to ground through a resistance R_{16} , the tone productive lead 1 being connected to the junction of the two resistances. A resistance R_{17} is connected from the grid G to ground. The anode-to-cathode circuit contains the source of anode potential $+B$ connected to the anode through the resistance R_6 . For tuning the oscillator to a desired frequency the foregoing parts are preselected in values, exact frequency being attained through adjustment of a trimmer condenser C_{25} connected in parallel with the condenser C_{24} .

I have found that the particular modification of a phase-shift oscillator set forth in Figure 5 has such sufficient frequency stability that it may be employed as a master oscillator for a cascade system in a musical instrument. However, I have also found that its stability may be suitably decreased by increasing the value of its resistance R_{15} , to the effect that the oscillator may be raised in frequency under the influence of controlling pulses from a source of oscillations of higher frequency, so that it operates as a frequency divider at an exact subharmonic of the frequency of the source. Still further, I have found by increasing further the value of the resistance R_{15} that the device becomes a non-self-oscillatory frequency divider, to operate similarly to the dividers of Figure 1.

I have therefore set forth in Figure 6 two uses of the oscillator modification of Figure 5. In the left of Figure 6 the device is employed as a master oscillator, operating at the frequency of the high C note 2093 C. P. S., whereas in the right of the figure it is employed as non-self-oscillatory frequency divider operating under the control of the left member at the 1046.5 C. P. S. C note, as the first member of a dependent cascade. Further members of the cascade are indicated by the arrows pointing toward the right from Figure 6.

A control lead 2 connected from the anode A of the master oscillator to the grid G of the first driven member, and containing the condenser C_{26} , is illustrated in the figure. The application of a tremolo to the master oscillator is indicated by the source Tr connected in series with the resistance R_{17} .

Since the driven member of Figure 6 operates at a different frequency from the master oscillator the values for corresponding parts will not necessarily be the same as in the master oscillator. I have therefore employed different indicia in the driven member where different values for corresponding parts are employed; for example the condenser C_{21} of the master oscillator becomes the condenser C_{27} of the driven member, and so on. In particular, the resistance R_{15} of the master oscillator becomes a larger resistance R_{18} in the driven member.

In Figure 7 the device of Figure 5 is employed as a filter circuit for modifying according to a particular tone color the various oscillations conducted to it from a keyboard system. I have therefore indicated the electrical aspects of a keyboard system at the left of Figure 7, including continuations of the leads 1 through which, as aforesaid, oscillations are derived from the generating devices of the foregoing figures. As illustrated in Figure 7 the outer ends of these leads 1 are connected to appropriate keyboard operated switches S . These switches preferably are of gradual contact character such as set forth in United States Patent No. 2,215,124 issued September 17, 1940, to John F. Jordan and myself as joint patentees for Electrical contacts. The other ends of the switches S are connected to an oscillation collector 4, which I have illustrated by a dashed line to indicate the inclusion of other connections thereto than those specifically shown. The collector 4 terminates in a resistance R_{19} connected to ground, the tone color device of the figure being connected to the resistance R_{19} through a lead 5 containing the condenser C_{31} . A lead 6 is also connected to the resistance R_{19} to indicate the connection of further tone color devices thereto.

In principle the tone color device of Figure 7 functions similar to a resonating circuit, modifying complex oscillations conducted to it by altering their harmonic content within a predetermined frequency. For this purpose therefore, the device is arranged to be non-self-oscillatory; consequently it employs the resistance R_{18} , similar to the non-self-oscillatory driven member of Figure 6. As an example I will arrange the device of Figure 7 to resonate in a frequency band centering approximately at 2000 C. P. S.; under this example its condensers C_{21} and C_{22} therefore correspond to the similar condensers in the master oscillator of Figure 6 whereas its condenser C_{23} approximates the mean value of the condenser combination C_{24} , C_{25} of the former. Modified oscillations are derived from the tone color device through a lead 7 connected to the junction point of a condenser and resistance in series between the anode A and ground, the condenser C_{33} being connected to the anode with the resistance R_{20} connected to ground. This lead 7 contains a switch S which will be similar in character to those of the aforementioned Patent No. 2,215,124.

While in the above I have described tubes T each having evacuated enclosures containing the elements for a single thermionic vacuum tube I prefer to employ double tubes, so called, in commercial embodiments of my invention. Such

double tubes, each containing the elements for two vacuum tubes, have the advantage of requiring only one half the apparent number of tubes which would otherwise be required, thus considerably reducing the cost and space required. I find that a commercial type of double tube known as a 7F7 is satisfactory for the purpose, and in conjunction with this the following values for other parts in the particular exemplary embodiments given above, are suitable:

+B=250 volts	C ₆ =.002 mfd.
-V=250 volts	C ₇ =.001 mfd.
L ₂ =4 henries	C ₈ =.002 mfd.
L ₂ /L ₁ =6/1 turns ratio	C ₉ =.00025 mfd.
R ₁ =250,000 ohms	C ₁₀ =.004 mfd.
R ₂ =500,000 ohms	C ₁₁ =.002 mfd.
R ₃ =1,000,000 ohms	C ₁₂ =.004 mfd.
R ₄ =500,000 ohms	C ₁₃ =.0005 mfd.
R ₅ =4,000 ohms	C ₁₄ =.008 mfd.
R ₆ =100,000 ohms	C ₁₅ =.004 mfd.
R ₇ =50,000 ohms	C ₁₆ =.008 mfd.
R ₈ =adjustable	C ₁₇ =.001 mfd.
R ₉ =100,000 ohms	C ₁₈ =.016 mfd.
R ₁₀ =1,500 ohms	C ₁₉ =.008 mfd.
R ₁₁ =1,000 ohms	C ₂₀ =.016 mfd.
R ₁₂ =5,000 ohms	C ₂₁ =.0005 mfd.
R ₁₃ =200,000 ohms	C ₂₂ =.0005 mfd.
R ₁₄ =200,000 ohms	C ₂₃ =.01 mfd.
R ₁₅ =50,000 ohms	C ₂₄ +C ₂₅ =.00125 mfd.
R ₁₆ =2,000 ohms	C ₂₆ =.001 mfd.
R ₁₇ =2,000,000 ohms	C ₂₇ =.001 mfd.
R ₁₈ =100,000 ohms	C ₂₈ =.001 mfd.
R ₁₉ =5,000 ohms	C ₂₉ =.002 mfd.
R ₂₀ =100,000 ohms	C ₃₀ =.002 mfd.
C ₁ +C ₂ =.00147 mfd.	C ₃₁ =.001 mfd.
C ₃ =.001 mfd.	C ₃₂ =.001 mfd.
C ₄ =.002 mfd.	C ₃₃ =.01 mfd.
C ₅ =.00025 mfd.	

It will be understood that modifications can be made in my invention without departing from its spirit. Being thus described those features of the invention which I consider new and novel and which I desire to protect by Letters Patent, comprise:

1. An oscillation generating system for an electrical musical instrument, comprising a source of stabilized oscillations arranged to operate at a frequency corresponding to a note in high octave register of a musical scale, and a series of frequency dividers comprising each an amplifying vacuum tube containing an anode, a thermionic cathode and a control grid, an anode-to-cathode circuit containing a source of anode potential, a grid-to-cathode circuit containing a phase shifting network comprising a combination of capacities and resistances, and a connection between said anode-to-cathode circuit and said network, said dividers being arranged successively to resonate below respective sub-octaves relative to said source, a connection between said source and the grid-to-cathode circuit of the first divider of said series and a connection between the anode-to-cathode circuit of each preceding divider to the grid-to-cathode circuit of the adjacent succeeding divider, and connections to alternate ones of said dividers for

deriving oscillations therefrom in phase with the oscillations in the plate circuits thereof, and connections to the remaining oscillators to deriving oscillations therefrom out of phase with the oscillations in the plate circuits of the said oscillators, whereby under successive influence originating at said source said dividers operate at successive suboctaves thereof to provide octavely related oscillations for tone production.

2. Apparatus as set forth in claim 1, wherein there is insufficient transfer of phase-shifted oscillations within said dividers respectively to provide completely self-sustained oscillations therein, whereby under influence of said source as stated, said dividers operate as non-self-oscillatory frequency dividers.

3. Apparatus as set forth in claim 1, wherein said connections for deriving oscillations from said dividers comprise connections to said phase shifting networks in alternate dividers and connections to said cathodes in the remaining dividers, whereby oscillations as derived from said dividers are substantially in phase.

4. Apparatus as set forth in claim 1, wherein said connections for deriving oscillations from said dividers comprise connections to said phase shifting networks in alternate dividers and connections to said cathodes in the remaining dividers, whereby oscillations as derived from said dividers are substantially in phase, and wherein a source of negative potential is connected to said cathodes in said remaining dividers to impede the inclusion of direct current shocks in oscillations derived therefrom.

5. Apparatus as set forth in claim 1, wherein said source of stabilized oscillations consists of a phase-shift oscillator comprising an amplifying vacuum tube containing an anode, a thermionic cathode and a control grid, an anode-to-cathode circuit containing a source of anode potential, a grid-to-cathode circuit containing a phase shifting network, wherein said network comprises at least two capacities connected in series to said grid and shunted by at least two resistances in series, a resistance connected between the junction point of said capacities and said cathode, and a capacity connected between the junction point of said resistances and said cathode, and a connection between said anode-to-cathode circuit and said network.

6. Apparatus as set forth in claim 1, wherein said dividers consist each of a phase-shift device comprising an amplifying vacuum tube containing an anode, a thermionic cathode and a control grid, an anode-to-cathode circuit containing a source of anode potential, a grid-to-cathode circuit containing a phase shifting network, wherein said network comprises at least two capacities connected in series to said grid and shunted by at least two resistances in series, a resistance connected between the junction point of said capacities and said cathode, and a capacity connected between the junction point of said resistances and a connection between said anode-to-cathode circuit and said network.

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