July 1, 1941. N. LANGER 2,247,728

OSCILLATION GENERATOR FOR ELECTRICAL MUSICAL INSTRUMENTS

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Fig. 1.

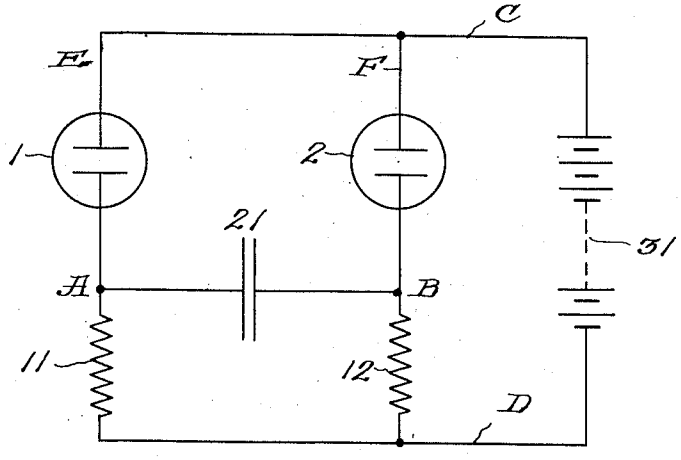
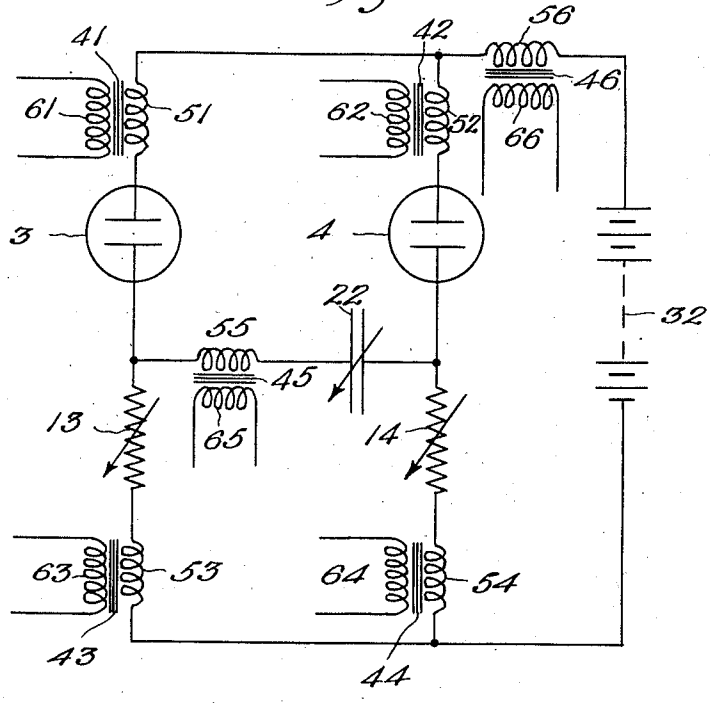


Fig. 2.



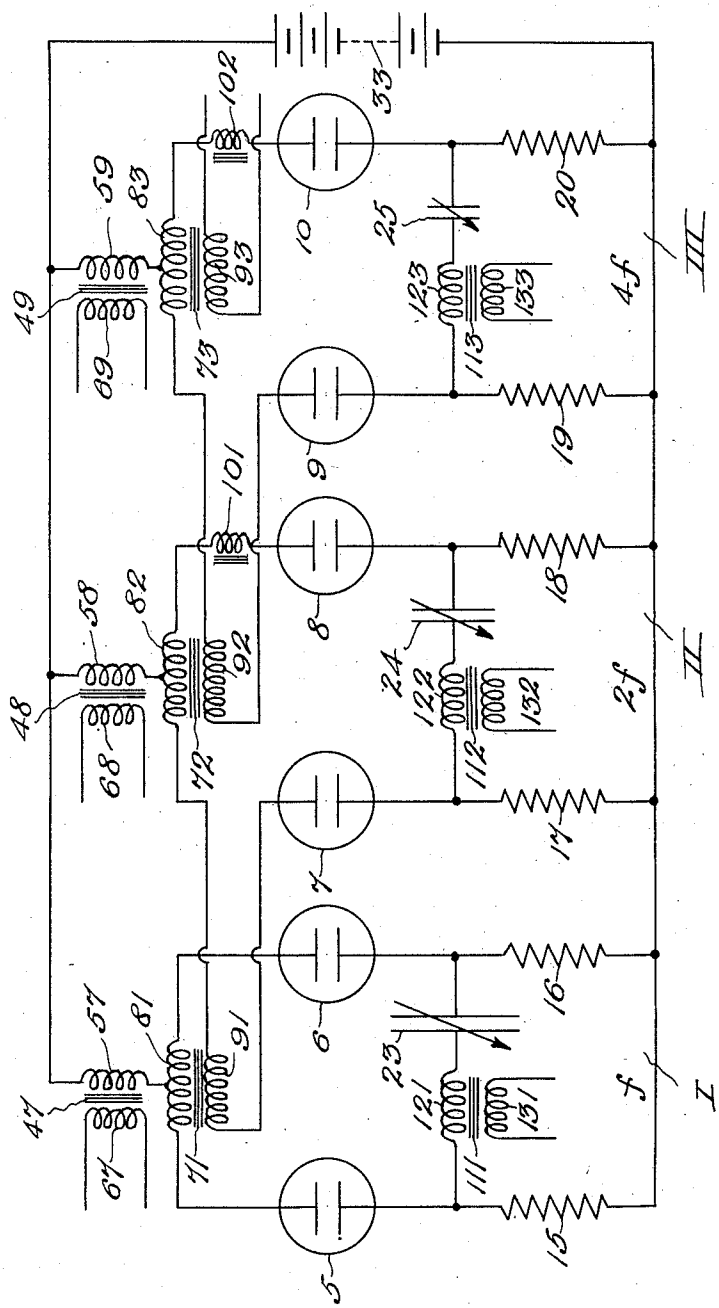
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OSCILLATION GENERATOR FOR ELECTRICAL MUSICAL INSTRUMENTS

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Fig. 3.



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2,247,728

OSCILLATION GENERATOR FOR ELECTRICAL MUSICAL INSTRUMENTS

Nicholas Langer, New York, N. Y., assignor of sixty-six and two-thirds per cent to John Halmagyi, New York, N. Y.

Application February 13, 1939, Serial No. 256,101

23 Claims. (Cl. 250—36)

The present invention relates to the art of producing electrical oscillations, and, more particularly, to an oscillation generator for the production of electrical oscillations of musical frequency in which a condenser is periodically charged and discharged through resistances and glow-discharge tubes.

It is an object of the present invention to provide an oscillation generator of novel and improved character in which alternate electrical discharges take place in a plurality of glow-discharge tubes and cooperate in generating electrical oscillations of a complex and desirable wave form.

It is another object of the invention to provide an oscillation generator of the glow-discharge tube type which is capable of producing electrical oscillations having a substantially constant frequency and including very strong harmonics of a desirable character.

It is a further object of the invention to provide an oscillation generator involving a pair of glow-discharge tubes which are alternately energized through a system of resistors and at least one condenser and capable of producing an oscillation of musical frequency in some of the parts of the circuit and an oscillation of double of such frequency in other parts of the circuit.

Still another object of the invention is to provide a twin glow-discharge tube oscillator including a pair of glow-discharge tubes through which alternate discharges take place when combined in a suitable manner with a condenser and with a pair of resistances, without requiring any inductances in the circuit.

The invention also contemplates a system of oscillation generators each being capable of producing an electrical oscillation of musical frequency and its octave combined in such a manner that oscillatory energy is transferred from each oscillator of the system to a subsequent oscillator thereby to establish preferred and constant frequency relationships throughout the system.

It is also within contemplation of the invention to provide an electrical musical instrument including a plurality of twin glow-discharge tube oscillation generators, each comprising a pair of alternately excited glow-discharge tubes and producing electrical oscillations of musical frequency having the interval of one octave therebetween and having interrelations between subsequent oscillators of the series to positively maintain said octave interval constant.

Other and further objects and advantages of the invention will become apparent from the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 illustrates a novel circuit embodying the present invention and employing a pair of glow-discharge tubes in cooperating relation for the production of electrical oscillations;

Fig. 2 depicts a similar circuit for the production of electrical oscillations of musical frequency and includes a plurality of coupling members for withdrawing oscillations of different frequency and wave-form from the various parts of the circuit; and

Fig. 3 shows a system of oscillation generators of the type illustrated in Figs. 1 and 2 for the purpose of producing a plurality of oscillations of musical frequency having a stable and positively constant frequency interval therebetween.

Broadly stated, according to the principles of the present invention, the foregoing objects are attained by electrically associating two or more glow-discharge tubes into a circuit in such a manner that the oscillatory current set up by one of them influences the production by the others, and vice versa. Thus, two glow-discharge tubes may be electrically associated with each other so that the voltage on one of the tubes depends on the momentary condition of the other, whether it is conducting current at that particular moment contemplated, or not. I have discovered that when such interrelations are established between glow-discharge tubes, a number of individual oscillations will be set up in different parts of the circuit These oscillations may have frequency and phase differences and such frequency and phase differences are automatically maintained constant indefinitely even though the electromotive force, the capacities and the resistances in the circuit, or the characteristics of the glow-discharge tubes may vary considerably.

More particularly, I have made the discovery that a pair of glow-discharge tubes may be combined with a source of direct current potential, with a pair of resistances and with a single condenser to produce electrical oscillations of great frequency constancy and amplitude and containing very strong harmonics. Moreover, I have found that in circuits of the character described, the harmonic content of the oscillations greatly varies in the various parts of the circuits according to whether the part of the circuit contemplated is in common for both glow-discharge tubes, or not. Thus, some parts of the circuit carry strong currents having twice the frequency of the oscillatory currents set up in other parts of the circuit.

This interesting and important property of my novel glow-discharge tube oscillators may be put to use with great advantage in the construction of electrical musical instruments in that a plurality of oscillations of different frequency and of different wave-form of harmonic content may be derived from a single oscillation generator. As a further development of this basic inventive concept, a plurality of such oscillation generators are provided, each producing oscillations which are separated from each other by a predetermined interval, such as an octave. In addition to this oscillation, each oscillation generator also produces an oscillation of the same frequency as that of the next oscillation generator and this oscillation may be introduced into the next generator to exert a strong locking and stabilizing influence thereon which cannot be destroyed or interrupted even by very great changes in the controlling factors of the individual glow-discharge tube oscillators, such as in the capacities, resistances, critical voltages of the tubes, and the like. Thus, a system of glow-discharge tubes is provided which is self-stabilizing in that the individual oscillation generators mutually assist each other in maintaining constant frequency intervals therebetween. Thus, not only a large number of constant frequency oscillations may be produced but at the same time a large number of different wave-forms of the various frequencies may be derived from the various portions of the system, as it will be explained more fully hereinafter.

Referring now more particularly to Fig. 1 of the drawings, a fundamental circuit embodying the principles of my invention is illustrated which in the following will be referred to as a "twin glow-discharge tube oscillator" or simply "twin oscillator." Essentially, a pair of glow-discharge tubes 1 and 2 is provided, each being connected in series with a resistance 11 and 12, respectively. Both tube 1 with its series resistance 11 and tube 2 with its series resistance 12 are connected across a suitable source of direct current 31 having a voltage in excess of the breakdown voltage of the tubes. A condenser 21 is connected between the common terminal of tube 1 and resistance 11 and the common terminal of tube 2 and resistance 12.

As to the electrical constants of the circuit, wide variations are possible. Preferably, the tubes are of a similar type although this consideration is by no means critical as tubes of widely varying break-down and extinction voltages can be employed in the twin oscillator circuit. Generally speaking, the resistances and the condenser have similar values as employed in the single glow-discharge tube oscillation generators such as are described in my U. S. Patent No. 1,832,402, granted November 17, 1931. To give a practical example, if condenser 21 is about 0.001 microfarad, resistances 11 and 12 are about 2 megohms each, and the voltage of direct current source 31 is about 100 volts, oscillations of musical frequency will be set up in the circuit.

The study of the oscillatory processes in a circuit of this type is greatly facilitated when the capacity of condenser 21 is made very large, such as several microfarads. In this case, the oscillations set up in the circuit become extremely slow, only one oscillation or current impulse in several seconds, so that the flow of current in the different parts of the circuit and through the individual glow-discharge tubes may be studied at leisure.

When the circuit illustrated in Fig. 1 is completed, it will be found that both tubes 1 and 2 will be periodically lit and extinguished at predetermined constant time intervals. It will be also observed that the two tubes are never lit at the same time but when tube 1 is lit, tube 2 is always extinguished, and vice versa. Thus, two electrical oscillations are produced in the circuit, said oscillations having the same frequency but having a constant phase difference. The phase difference varies with the proportion of the resistances 11 and 12 and is approximately 180 degrees when the two resistances are equal. Of course, instead of employing two fixed resistances as indicated in Fig. 1, it is also possible to employ two variable resistances of appropriate value, or a single resistance having an intermediate tap which is connected to the lower terminal of the battery, or, finally, a single resistance having a sliding contact thereon whereby the phase difference between the two twin oscillations may be readily adjusted to a predetermined and preferred value. Of course, when it is desired to produce oscillations of musical frequency, such as are required in the construction and operation of electrical musical instruments, capacities of about 0.0001 to about 0.01 microfarad are employed in the circuit and of particular interest is the case when the resistances 11 and 12 are substantially equal.

The reasons for this type of operation of the circuit are not completely clear and I do not wish to attempt a theoretical explanation of such operation, although an approximate idea may be formed as to the reason why the two glow-discharge tubes will never be lit at the same time. It may be assumed that in all cases there is a slight difference between the breakdown voltage of tubes 1 and 2. Assuming that tube 1 has the lower break-down voltage, a momentary discharge will take place through this tube, and through resistance 11 which is in series therewith. As soon, however, as current flows through the branch of the circuit containing tube 1 and resistance 11, a difference of potential will be caused between the common terminal of tube 1 and resistance 11 and the common terminal of tube 2 and resistance 12, between the which condenser 21 is connected. This difference of potential will cause charging of the condenser and this charging current will reduce the potential available for tube 1 still further so much that it will fall below the extinction voltage thereof. As soon, however, as tube 1 is extinguished, condenser 21 will add its voltage to that of the voltage applied to tube 2, which now will break down and will discharge condenser 21. This discharge will lower the potential of common terminal B below that of A, so that condenser 21 will be again charged in the opposite direction than before. This charge and discharge of condenser 21 and the alternate discharges through tubes 1 and 2 will be periodically repeated indefinitely so long as current is supplied to the circuit. The number of discharges per second, in other words, the frequency of the oscillations set up in the circuit increases with increasing voltage of direct current source 31 and decreases with increasing capacity of condenser 21, or with increasing resistance of resistances 11 and 12, same as in the case of the simple glow-discharge tube oscillator. Obviously, the number of discharges during a predetermined time interval must be exactly the same through tubes 1 and 2, there being, however, always a constant phase difference, for ex-

ample, 180 degrees, between these oscillatory currents. In the part of the circuit which is in common for both tubes, such as leads C and D of the common source of current, both oscillatory currents will be present. This resultant current will be extremely rich in harmonics, as it will contain the fundamental and the harmonics of both oscillations produced in the individual branches of the circuit. Particularly the second harmonic, or the octave, of the oscillations produced in the individual branches of the circuit will be very strongly expressed in the common branch of the circuit. Those skilled in the art will readily appreciate that this is of very great practical importance as both a fundamental frequency and its octave may be simultaneously derived from my novel twin glow-discharge tube oscillator. Thus, two oscillations may be obtained which always have the constant interval of an octave between their respective frequencies, a circumstance which is of great interest and value in the construction and operation of electrical musical instruments capable of producing musical chords.

Of course, oscillatory currents of different character and frequency will flow in the different portions of the oscillation generator illustrated in Fig. 1. Thus, as it has been set forth in the foregoing, in leads E and F, in which only current of a single glow-discharge tube flows, complex oscillations of identical frequency will flow having a constant phase difference and a fairly strong amplitude. In resistors 11 and 12 currents of the same frequency will flow as in leads E and F, respectively, however, they will have a smaller amplitude than the former and will be somewhat poorer in harmonics in view of the fact that not all of the current passing in leads E and F will pass through resistances 11 and 12 but some of it will flow over condenser 21. In leads C and D very strong oscillations will be present as in these leads the currents flowing through both tubes will be superimposed upon each other. In other words, in leads C and D a very complex oscillatory current will be present which generally speaking contains the octave of the fundamental and of all of the harmonics individually present in leads E and F. In the branch of the circuit between points A and B which contains condenser 21, an oscillation will be generated having the same frequency as the fundamental of the oscillations in leads E or F. I have found by experiment that the oscillation in this particular portion of the circuit comes quite close to a pure sinus wave and is capable of producing a very pleasing and soft musical tone when converted into sound vibrations by means of a suitable translating device.

Fig. 2 depicts a circuit similar to the one illustrated in Fig. 1 with the difference, however, that coupling means are provided in the various portions of the circuit to selectively withdraw oscillatory energy of different frequency, or of different wave-form, or both. Although in this modified embodiment transformers have been shown as coupling means, obviously coupling means of various type, such as condensers, chokes, resistances, and combinations thereof may be employed for the selective withdrawal of oscillatory energy with equal or similar results. In other words, the coupling means may be of an inductive, capacitive, or galvanic character and preferably provide a coupling loose enough to prevent the reflection of energy from the external or load circuit into the oscillation generator proper, as such reflection might interfere with the stability of the oscillations produced or might introduce undesirable harmonics into the oscillation generator.

In Fig. 2 essentially the same elements are employed as in the circuit of Fig. 1. Thus, a glow-discharge tube 3 is connected in series with a resistance 13 and a second glow-discharge tube 4 is connected with a resistance 14. Likewise, same as in Fig. 1, a condenser 22 is connected across the common terminal of tube 3 and resistance 13 and the common terminal of tube 4 and resistance 14. Direct current voltage is applied to both tubes 3 and 4 and to their respective series resistances 13 and 14 from a suitable source of direct current 32. As it will be readily observed from Fig. 2, the tubes and their resistances are not directly connected to the source of current but through the primary windings of a plurality of transformers 41, 42, 43, 44 and 45. Thus, primary winding 51 of transformer 41 is interposed in series with the upper lead of tube 3, primary winding 52 of transformer 42 is interposed in series with the upper lead of tube 4, primary winding 53 of transformer 43 is connected in series with the lower end of resistance 13 and primary winding 54 of transformer 44 is connected in series with the lower end of resistance 14. In addition to this, primary winding 56 of transformer 46 is connected directly in series with the source of current 32 in the common or main branch of the circuit in which current from both tubes is flowing, and primary winding 55 of transformer 45 is connected in series with condenser 22. Thus, from secondary windings 61, 62, 63, 64, 65 and 66 of the transformers, six oscillations of different character may be simultaneously derived. The oscillations derived from secondary windings 61 and 62 are identical in frequency and in their harmonic content but they are displaced in phase by a constant amount. Likewise, secondary windings 63 and 64 provide oscillatory currents of the same frequency as 61 and 62 and also have a constant phase difference therebetween but they are considerably poorer in the higher harmonics. Secondary winding 66 supplies oscillatory energy from the main branch of the circuit, having double the frequency of the oscillations derived from the secondary windings and having strong harmonics and a great amplitude, whereas secondary winding 65 delivers substantially sinusoidal oscillations of the same frequency as secondaries 61 or 62, but relatively poor in harmonics. Preferably, condenser 22 is of an adjustable capacity in order to adjust the frequency of the oscillations produced and resistances 13 and 14 are also of an adjustable character in order to adjust the phase difference between the oscillations in the various parts of the circuit to a predetermined and preferred value. As it will be readily understood by those skilled in the art, the circuit of the type described in connection with Fig. 2 has great value for the production of musical sounds in electrical musical instruments as a number of oscillations of different character and of constant frequency intervals may be generated by a single circuit, such as those imitating the musical qualities of the diapason, flute, string and reed stops of a pipe organ. Moreover, sounds of a predetermined frequency and the octave of such sounds may be simultaneously produced, any deviations from the true relative tuning being positively prevented. Of course, instead of employing 6 output transformers in the

various parts of the circuit, transformers or similar coupling means more or less in number than six may be employed according to other practical considerations.

Very naturally, in an electrical musical instrument, a large number of oscillation generators is required, generally speaking one oscillation generator for each note of the musical range of the instrument, such as 88, or more, in number. This is not objectionable, in view of the fact that the glow-discharge tubes, of which two are required for each generator, and also the other elements of the generator, are small in dimensions and are low in cost. It is very desirable, however, to positively assure that constant frequency intervals are maintained between the individual generators. This can be accomplished by transferring small amounts of oscillatory energy from one oscillation generator to the others. My twin glow-discharge tube oscillator is particularly adaptable for carrying this concept into practice in view of the fact that from each oscillation generator a fundamental frequency and its octave can be readily derived simultaneously. For this reason, it is preferred to establish such inter-relation between a series or system of twin oscillators which are tuned to subsequent octaves, for reasons which will appear more fully hereinafter.

A circuit of such character is depicted in Fig. 3. Although only 3 twin oscillators are illustrated tuned one octave apart from each other, obviously, any suitable number of similar oscillators may be employed, such as 7 or 8, in order to provide the successive octaves of a note of the tempered scale for the full musical range. As it will be readily understood from the drawings, each of the three twin oscillators I, II, and III is substantially similar to the ones depicted in Figs. 1 and 2. Thus, oscillation generator I comprises a pair of glow-discharge tubes **5** and **6**, which are connected in series with resistances **15** and **16**, respectively, and a variable condenser **23** is connected between the common terminal of tube **5** and resistance **15** and the common terminal of tube **6** and resistance **16**. Likewise, twin oscillator II essentially comprises glow-discharge tubes **7** and **8** connected in series with resistances **17** and **18**, respectively, and having a variable condenser **24** connected between the common terminal of tube **7** and resistance **17** and the common terminal of tube **8** and resistance **18**. Twin oscillator III comprises glow-discharge tubes **9** and **10**, connected in series with resistances **19** and **20**, respectively, and a variable condenser **25** is connected between the common terminal of tube **9** and resistance **19** and the common terminal of tube **10** and resistance **20**. Direct current potential is supplied to all three twin oscillators from a source **33**. Oscillator I is supplied with current through the primary winding **81** of a transformer **71**, the two ends of said winding being connected to tubes **5** and **6**, respectively, while a center tap of primary winding **81** being connected to the upper terminal of source **33** through the primary winding **57** of an output transformer **47**. Oscillator II is supplied with current through the secondary winding **91** of transformer **71** having one of its ends connected to tube **7** and having its other end connected to primary winding **82** of a transformer **72**, the other end of said primary winding **82** being connected through a choke coil **101** to tube **8**. The center tap of the primary winding **82** of transformer **72** is connected to the upper terminal of source **33** through the primary winding of output transformer **48**. Oscillator III is supplied with current through the secondary winding **92** of transformer **72** having one of its ends connected to tube **9** and having its other end connected to primary winding **83** of transformer **73**, the other end of said primary winding **83** connected through a choke coil **102** to tube **10**. The center tap of the primary winding **83** of transformer **73** is connected to the upper terminal of source **33** through the primary winding **59** of output transformer **49**. Secondary winding **93** of transformer **73** is provided for connection to one of the tubes of the subsequent twin oscillator and to its transformer corresponding to similar elements of twin oscillator III. In addition to output transformers **47**, **48**, and **49**, similar output transformers **111**, **112** and **113** are provided having their primary windings **121**, **122** and **123** in series with condensers **23**, **24**, and **25**, respectively.

From the preceding description, operation of the circuit illustrated in Fig. 3 will be readily understood by those skilled in the art. The electrical constants of twin oscillators I, II and III are so selected and condensers **23**, **24** and **25** are so adjusted that if the fundamental frequency produced by twin oscillator I is denoted by f, twin oscillator II produces a fundamental frequency of $2f$, and twin oscillator III produces a fundamental frequency of $4f$. Of course, any suitable number of such twin oscillators may be connected in the same manner, subsequent oscillators of the series having fundamental frequencies of $8f$, $16f$, etc. Generally speaking, it is not necessary to provide variable resistors, but resistances **15** and **16** may be fixed resistors of equal value, same as resistances **17** and **18**, **19** and **20**.

Referring now more particularly to twin oscillator I, it will be readily observed that this oscillator is substantially identical with the circuit shown in Fig. 1. Therefore, oscillations of constant frequencies will be produced in the various portions of the circuit. In accordance with the principles governing the production of such oscillations explained in the foregoing, the lowest of the frequencies produced will be f, and such oscillation will be present, for example, in the windings of output transformer **111**, in the portions of the circuit directly in series with tube **5** or with tube **6**. However, as the primary of push-pull transformer **71** is in series with both tubes **5** and **6**, oscillations having a frequency of $2f$ will be produced therein and an electro-motive force of such double frequency will be present in the secondary winding **91** of such transformer.

The conditions will be similar in twin oscillator II in which electrical oscillations will be set up having a fundamental frequency of $2f$. Therefore, in series with tube **7** alone, the frequency will be $2f$, that is the same as the electro-motive force across secondary winding **91** which is connected in series with tube **7**. In case the polarity of secondary winding **91** is correctly selected with respect to the phase of the oscillations through tube **7**, these oscillations of identical frequency will be in step with each other so that the oscillations of twin oscillator I will exert an extremely strong stabilizing influence upon the frequency of the oscillations produced by twin oscillator II. Experiments have demonstrated that this stabilizing influence is so strong that even very great and intentional changes in the electrical constants of twin oscillator II are incapable of pulling it apart and the exact frequency interval of one octave will be maintained indefinitely,

even in the case when great changes occur in the electrical constants of circuit II. The object of choke **101** is merely to obtain balance in the inductances interposed in series with tubes **7** and **8** respectively, and its inductance is so selected as to substantially equal that of secondary winding **91**. However, as this requirement is by no means critical, the choke coil may be omitted without detrimental effects.

The same remarks apply to twin oscillators II and III which are connected with each other in the same manner as oscillators I and II. In view of the fact that the primary winding **82** of push-pull transformer **72** is connected in series with both tubes **7** and **8**, oscillations of a frequency of $4f$ will be set up in secondary winding **92** which is connected in series with tube **9** of twin oscillator III of which the fundamental frequency equals $4f$. Thus, the double frequency $4f$ of oscillator II will be impressed upon the portion of oscillator III in which a current of the frequency of $4f$ is flowing and will exert a strong stabilizing influence thereon. It will be readily understood that the frequency of oscillator III cannot be changed individually due to the great stabilizing influence exerted thereon. Such change would be possible only in the event that the frequency of oscillator II is changed first. This latter frequency, however, is incapable of individual change except when the frequency of oscillator I is first changed. Therefore, the system will automatically and positively maintain its respective frequency intervals and even intentional changes in the frequency cannot be obtained unless by changing the frequency of oscillator I upon which the operating frequencies of all subsequent frequencies are based. Secondary winding **93** of push-pull transformer **73** has an oscillation present therein having a frequency of $8f$, which may be transferred to a subsequent twin oscillator IV (not shown) of similar character and tuned to a fundamental frequency of $8f$, as those skilled in the art will readily understand.

As to the withdrawal of the oscillations for example for the purpose of an electrical musical instrument, this is accomplished by means of output transformers or by means of similar coupling members. As a matter of fact, any desired number of output transformers may be provided in the various parts of the several circuits, the most important possibilities having been indicated in Fig. 2. Thus, in Fig. 3, output transformers **111**, **112** and **113** having secondary windings **131**, **132** and **133** will produce oscillations of respective fundamental frequencies of f, $2f$, and $4f$ of a substantially sinusoidal character. In contrast to this, output transformers **47**, **48** and **49** will produce oscillations of very complex character and very rich in the higher harmonics, the respective frequencies in secondary windings **67**, **68** and **69** being $2f$, $4f$, and $8f$. In other words, the circuit of the character described is not only capable of producing a large number of oscillations having different and interlocking frequencies, but at the same time a plurality or series of oscillations may be simultaneously obtained having different harmonic content and thus being capable of producing sounds of different tone color corresponding to the various stops of the organ. Of course, the various oscillations derived from the various portions of the circuit may be further subjected to modifications of the harmonic content to obtain additional tone colors, as this is, for example, described more fully in my U. S. Patent No. 1,993,890, granted March 12, 1935.

Of course, the interval between the subsequent twin oscillators of the series is not restricted to an octave, but other suitable intervals such as fifth, sixth, etc., may be employed with equal or similar results. However, in view of the fact that in the tempered scale, now almost exclusively employed in keyboard instruments of constant tuning, only the octaves are in a rational proportion of frequencies, it is preferred to employ the octave interval. Likewise, it is to be observed that in order to obtain all of the notes of the musical range, it is necessary to provide a series or system of twin oscillators, similar to the one illustrated in Fig. 3, for each note of the tempered scale. Thus, a series of oscillators Ic, IIc, IIIc, IVc, Vc, etc., is to be provided for the subsequent octaves of the note *c*, a similar series of oscillators Ic♯, IIc♯, IIIc♯, IVc♯, Vc♯, etc. is to be provided for the note *c*♯, and a similar series I*d*, II*d*, III*d*, IV*d*, V*d*, etc. is to be provided for the note *d*, and so forth, throughout the 12 notes of the tempered scale. In a system of the described character, the problem of maintaining 88 or 90 individual oscillators in constant frequency intervals is reduced to the problem of maintaining the twelve lowest oscillators constant which is a relatively simple problem and may be accomplished in various ways such as for example by means of the frequency stabilizing system disclosed in my U. S. Patent No. 2,044,360 granted to me on June 16, 1936. In the event that the production of a tremolo effect is desired, in other words slight periodic changes of the frequencies produced, this can be accomplished by impressing a slow modulating oscillation having a frequency of 8 to 12 oscillations per second and produced, for example, by means of a separate glow-discharge tube oscillator, as this is fully disclosed in my U. S. Patent No. 2,040,439, granted May 12, 1936.

It will be noted that the circuits embodying the principles of the present invention provide important advantages heretofore difficult or impossible to obtain. Thus, first of all, a new and highly efficient oscillator of remarkably constant frequency is provided which is very simple and inexpensive in construction, small in dimensions, very moderate in its energy requirements, and is capable of producing oscillations of a very great frequency range extending from one oscillation in several minutes to oscillations beyond the audible range. These oscillations make it possible to produce musical sounds of widely different character, tone color, and frequency, simultaneously. The oscillations so produced have also great possibilities in time delay circuits wherein a very substantial, readily and accurately controlled time delay or very slow and equally spaced current impulses are required for time measuring, and the like. Moreover, as each discharge through the glow-discharge tubes is accompanied with light emission, it is possible to utilize such periodical emission of light impulses for various purposes, such as flashing light impulses for various purposes, such as flashing light and danger signals, advertising signs, annunciator systems, and the like.

Although the present invention has been described in connection with a few preferred embodiments thereof, variations and modifications may be resorted to by those skilled in the art without departing from the principles of the present invention. Thus, the circuit depicted

in Fig. 3 is merely illustrative of the inventive concept of transferring energy from one twin oscillator to a subsequent one of a series in order to maintain fixed frequency relationships therebetween. It will be readily appreciated that such transfer of stabilizing energy may be accomplished in many other ways, by means of coupling means of a different character, and the amount of such energy may be controlled, if desired, by means of adjustable coupling means, potentiometers, variocouplers, variable capacities, and the like. I consider all of these variations and modifications as within the true spirit and scope of the present invention as disclosed in the foregoing description and defined by the appended claims.

I claim:

1. An oscillation generator comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the common points of said tubes and resistances, and a source of direct current of constant potential connected across both of said tubes and resistances.

2. An oscillation generator comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the common points of said tubes and resistances, and a source of direct current of constant potential having a voltage in excess of the break-down voltage of said tubes connected across both of said tubes and resistances whereby oscillations of predetermined frequency will be produced.

3. An oscillation generator comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the two leads connecting said tubes to their respective resistances, and a source of direct current of constant potential for supplying electrical energy to both of said tubes through their respective resistances.

4. An oscillation generator comprising in combination a pair of glow-discharge tubes, each having only two electrodes, having one of their electrodes connected to each other, a condenser connecting the other two electrodes of said tubes, a pair of resistances having one of their ends connected to the two ends of said condenser respectively and having their other ends connected to each other, and means for applying direct current of constant potential to the leads connecting said two tubes and said two resistances with each other.

5. An oscillation generator comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the common points of said tubes and resistances, and a source of direct current of constant potential connected across both of said tubes and resistances whereby oscillations of different frequency and of different harmonic content will be produced in the different portions of said circuit, and means for withdrawing at least one of said oscillations of different frequency.

6. An oscillation generator comprising in combination an electrical circuit having a main portion and two branch portions, said branch portions being connected in series with said main portion, a source of direct current of constant potential in said main portion, a glow-discharge tube having only two electrodes and a series resistance in each of said branch portions, a condenser connected between the two intermediate leads of said branch portions connecting said tubes with their respective resistances whereby electrical oscillations of predetermined frequency and of constant phase difference will be set up in said branch portions and oscillations of double of such frequency will be set up in said main portion, and means for selectively withdrawing said oscillations.

7. An oscillation generator comprising in combination an electrical circuit having a main portion and two branch portions, said branch portions being connected in series with said main portion, a source of direct current of constant potential having an adjustable voltage in said main portion, a glow-discharge tube having only two electrodes and a variable series resistance in each of said branch portions, a variable condenser connected between the two intermediate leads of said branch portions connecting said tubes with their respective resistances whereby electrical oscillations of predetermined frequency and of constant phase difference will be set up in said branch portions and oscillations of double of such frequency will be set up in said main portion of said circuit, the phase relationship of said oscillations in said branch portions being varied when the relative values of said resistances are varied, and coupling means in said main and branch portions of the circuit for selectively withdrawing oscillations of different frequency, phase relationship and harmonic content therefrom.

8. An oscillation generator comprising in combination an electrical circuit having a main portion and two branch portions, said branch portions being connected across said main portion, a source of direct current in said main portion, a glow-discharge tube and a series resistance in each of said branch portions, a condenser connected between the intermediate leads of said branch portions connecting said tubes with their respective resistances, coupling means in said branch portions to withdraw oscillations of predetermined frequency and of substantial harmonic content, coupling means in the condenser branch of the circuit for withdrawing oscillations of low harmonic content and of the same frequency, and coupling means in said main portion of the circuit for withdrawing oscillations of substantial harmonic content and of double frequency.

9. An oscillation generator comprising in combination an electrical circuit having a main portion and two branch portions, said branch portions being connected across said main portion, a source of direct current in said main portion, a glow-discharge tube and a series resistance in each of said branch portions, a condenser connected between the intermediate leads of said branch portions connecting said tubes with their respective resistances, coupling transformers in said branch portions to withdraw oscillations of predetermined frequency and of substantial harmonic content, a coupling transformer in the condenser branch of the circuit for withdrawing oscillations of low harmonic content and of the same frequency, a coupling transformer in said main portion of the circuit for withdrawing oscillations of substantial harmonic content and

of double frequency, and means for adjusting said frequencies.

10. In an electrical musical instrument, the combination comprising a pair of oscillation generators tuned to frequencies in a simple numerical proportion to each other; each of said generators including a pair of glow-discharge tubes having only two electrodes, a resistance connected in series with each of said tubes, and a condenser connected between the leads connecting said tubes with their respective resistances; a source of direct current of constant potential in common for both generators, and coupling means for transferring oscillatory energy from one of said generators to the other to stabilize the frequency relationship of said generators.

11. In an electrical musical instrument, the combination comprising a plurality of oscillation generators tuned to frequencies in simple numerical proportion to each other; each of said generators including a pair of glow-discharge tubes having only two electrodes, a resistance connected in series with each of said tubes, and a condenser connected between the leads connecting said tubes with their respective resistances; a source of direct current of constant potential in common for all of said generators; and coupling means for impressing oscillatory energy from each generator upon the others to stabilize the frequency relationships of said generators.

12. In an electrical musical instrument, the combination comprising a plurality of oscillation generators tuned to frequencies in simple numerical proportion to each other; each of said generators including a pair of glow-discharge tubes having only two electrodes, a resistance connected in series with each of said tubes, and a condenser connected between the leads connecting said tubes with their respective resistances; a source of direct current of constant potential in common for all of said generators; coupling means for impressing oscillatory energy from each generator upon the others to stabilize the frequency relationships thereof; and means for withdrawing oscillatory energy of stabilized frequency from each of said generators.

13. In an electrical musical instrument, the combination comprising a plurality of oscillation generators tuned to successive octaves of a note of the tempered scale; each of said generators including a pair of glow-discharge tubes having only two electrodes, a resistance connected in series with each of said tubes, and a condenser connected between the leads connecting said tubes with their respective resistances; a source of direct current of constant potential for supplying energy to all of said generators whereby each will produce an oscillation of predetermined frequency and its octave; and means for impressing oscillatory energy from each generator onto the adjoining generator to stabilize the frequency relationship thereof.

14. In an electrical musical instrument, the combination comprising a plurality of oscillation generators tuned to successive octaves of a note of the tempered scale; each of said generators including a pair of glow-discharge tubes having only two electrodes, a resistance connected in series with each of said tubes, and a condenser connected between the leads connecting said tubes with their respective resistances; a source of direct current of constant potential for supplying energy to all of said generators whereby each of said generators will produce a fundamental oscillation of predetermined frequency and its octave; coupling means for impressing oscillations of octave frequency from each generator upon the oscillations of fundamental frequency of the next higher generator to stabilize the frequency thereof; and means for withdrawing oscillatory energy of stabilized frequency from each of said generators.

15. In an electrical musical instrument, the combination comprising a series of oscillation generators tuned to successive octaves of a note of the tempered scale; each of said generators having a main portion and two branch portions, said branch portions being connected across said main portion, a source of direct current in said main portion, a glow-discharge tube and a series resistance in each of said branch portions, and a condenser connected between the intermediate leads of said branch portions connecting said tubes with their respective resistance; coupling means for transferring oscillatory energy from the main portion of each generator onto the branch portion of the subsequent generator for stabilizing the frequency relationship thereof; and means for withdrawing oscillations of stabilized relative frequencies from each of said generators.

16. In an electrical musical instrument, the combination comprising a series of oscillation generators tuned to successive notes of the tempered scale along a plurality of octaves; each of said generators having a main portion and two branch portions, said branch portions being connected across said main portion, a source of direct current in said main portion, a glow-discharge tube and a series resistance in each of said branch portions, and a condenser connected between the intermediate leads of said branch portions connecting said tubes with their respective resistances; coupling means for transferring oscillatory energy from the main portion of each generator onto the branch portion of another generator tuned to a note of the tempered scale having the same name to stabilize the frequency relationship between the successive octaves of the same note; and means for withdrawing oscillations of musical frequency from each of said generators.

17. An optical signal comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the two leads connecting said tubes to their respective resistances, and a source of direct current of constant potential for supplying electrical energy to both of said tubes through their respective resistances whereby said tubes will alternately emit light at predetermined time intervals.

18. A flashing light signal comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resistance connected in series with each of said tubes, a condenser connected between the two leads connecting said tubes to their respective resistances, a source of direct current of constant potential for supplying electrical energy to both of said tubes through their respective resistances whereby electrical oscillations will be produced and said tubes will alternately emit light at predetermined time intervals, and means for adjusting the frequency of said oscillations for varying said time intervals.

19. An oscillation generator comprising in combination a pair of glow-discharge tubes, each of said tubes having only two electrodes, a resist-

ance connected in series with each of said tubes, a condenser connected between the two leads connecting said tubes to their respective resistances, a source of direct current of constant potential for supplying electrical potential to both of said tubes through their respective resistances, and coupling means for withdrawing substantially sinusoidal oscillations from the portion of said circuit in which said condenser is connected.

20. In an oscillation generator, the combination comprising a condenser, a resistance connected across said condenser to form a circuit of predetermined time constant therewith, a pair of glow-discharge tubes, each having only two electrodes, having one of their electrodes connected to the two plates of said condenser respectively, and means including a source of direct current of constant potential applied to the other electrodes of said glow-discharge tubes and to a point on said resistance to cause charging and discharging of said condenser in alternating directions at a rate determined by the time constant of said circuit.

21. In an oscillator of the character described, a pair of gaseous discharge tubes having only two electrodes, means for applying a potential between said electrodes for causing said tubes to become conductive, means occasioned by the breakdown of each tube for reducing the potential between the electrodes and extinguishing the conductivity of the other so that said tubes are alternately conductive, and means for producing an output voltage proportional to the current through one of said tubes.

22. In an oscillator of the character described, a pair of gaseous discharge tubes having only two electrodes, means for applying a potential difference between said electrodes for causing said tubes to become conductive, means occasioned by the breakdown of each tube for reducing said potential difference and extinguishing the conductivity of the other so that said tubes are alternately conductive, means for adjusting the relative periods of conductivity of said tubes, and means for producing an output voltage proportional to the current through one of said tubes.

23. In an oscillator of the character described, a pair of gaseous discharge tubes having only two electrodes, means for applying a potential between said electrodes for causing said tubes to become conductive, and means occasioned by the breakdown of each tube for reducing the potential between the electrodes and extinguishing the conductivity of the other so that said tubes are alternately conductive.

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