May 7, 1935.

V. J. ANDREW

2,000,685

CONTROL SYSTEM

Filed June 27, 1931

4 Sheets-Sheet 1

Fig. 1.

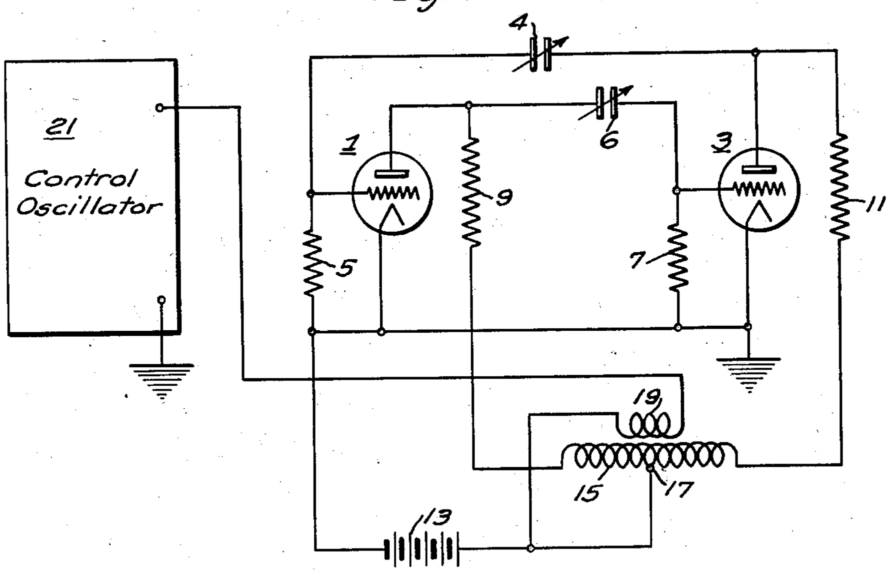
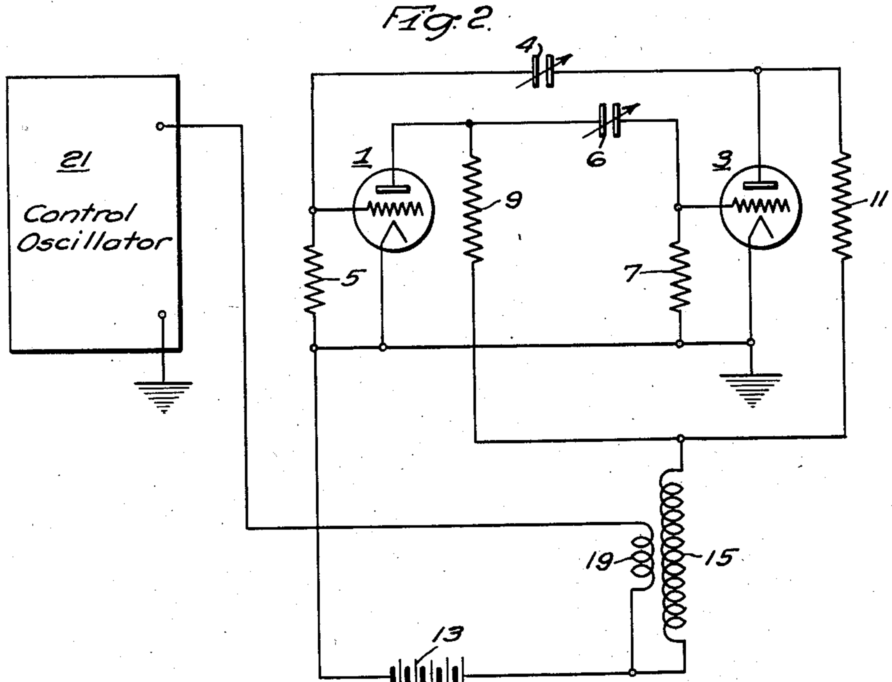


Fig. 2.



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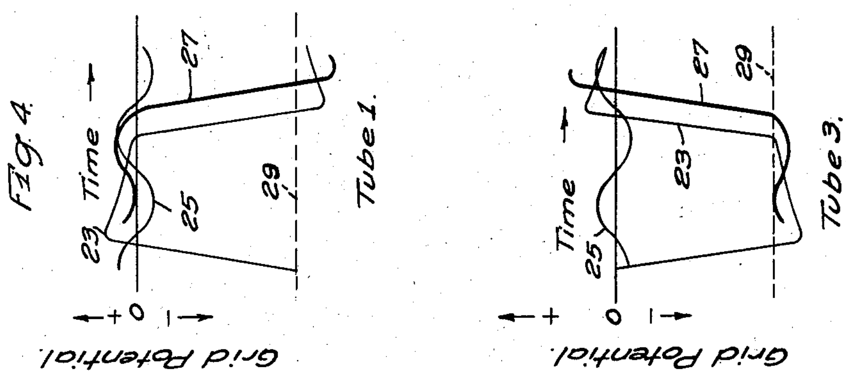
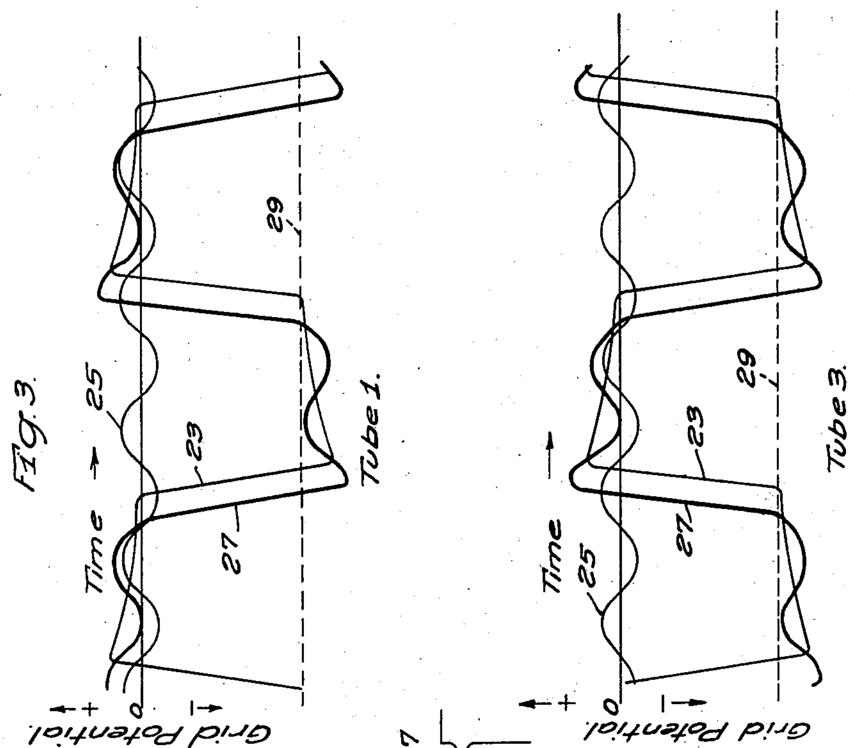
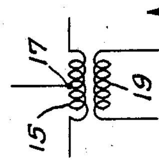
May 7, 1935. V. J. ANDREW 2,000,685

CONTROL SYSTEM

Filed June 27, 1931 4 Sheets-Sheet 2







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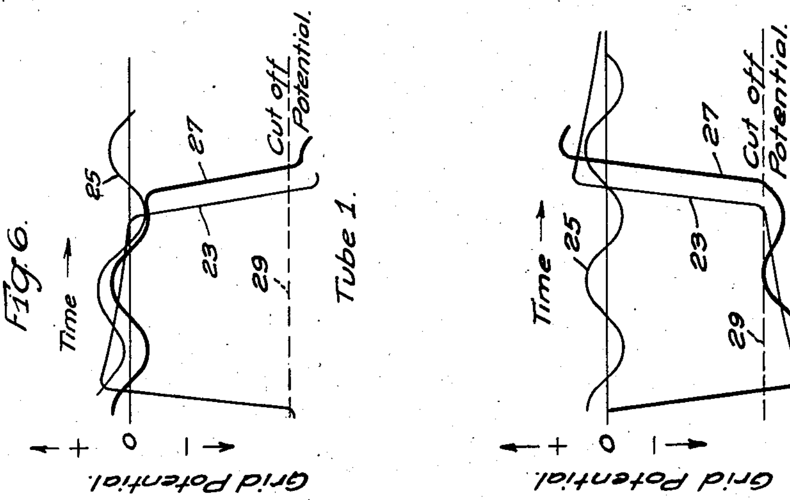
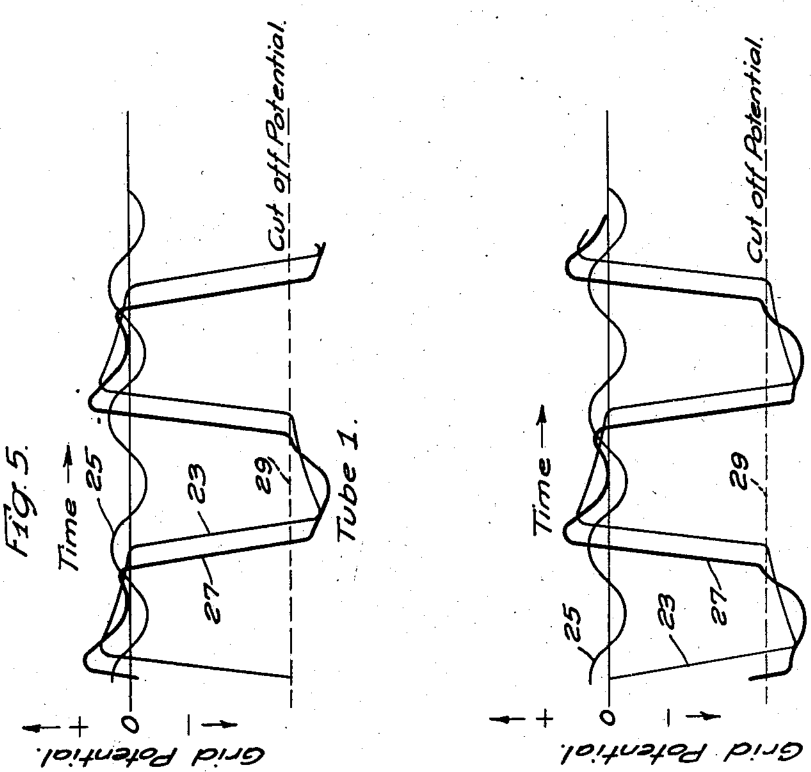
CONTROL SYSTEM

Filed June 27, 1931 4 Sheets-Sheet 3





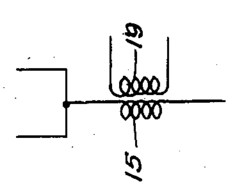


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Fig. 7.

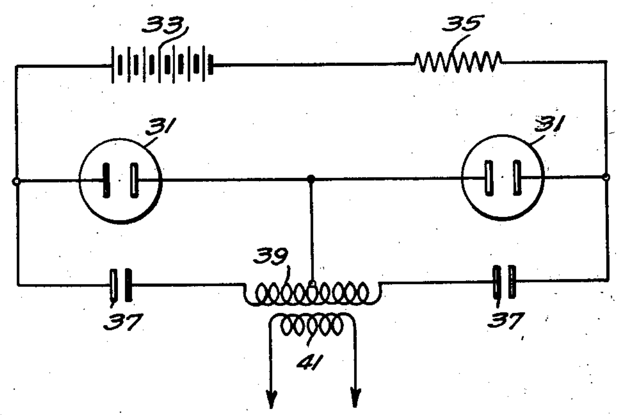
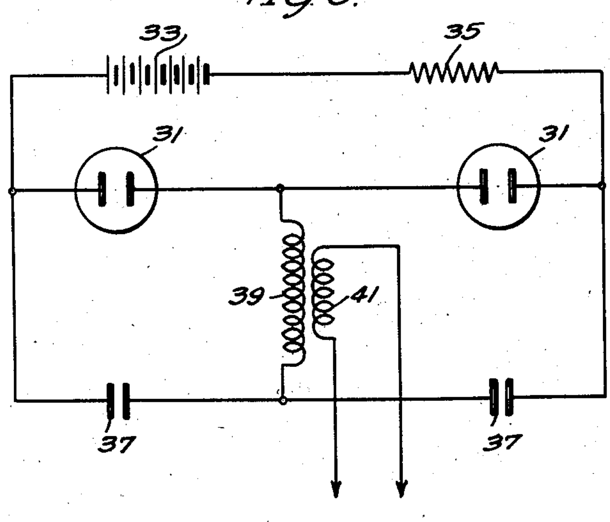


Fig. 8.



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Patented May 7, 1935 2,000,685

UNITED STATES PATENT OFFICE

2,000,685

CONTROL SYSTEM

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Application June 27, 1931, Serial No. 547,305

4 Claims. (Cl. 250—36)

My invention relates to oscillation generators, more particularly to means for controlling the frequency and stabilizing the operation thereof.

It is one object of my invention to provide means for controlling the frequency of an oscillator which means shall exert its controlling influence over a greater shift in the frequency of the oscillator than heretofore.

Another object of my invention is to provide means whereby the frequency of an oscillator may be controlled only by alternate harmonic frequencies of its fundamental.

Another object of my invention resides in a simple and convenient means whereby the above objects of my invention may be realized.

Additional objects of my invention will be disclosed in the following description of the same, taken in conjunction with the accompanying drawings wherein:

Figs. 1, 2, 7 and 8 are schematic diagrams representing embodiments and modifications of my invention.

Figs. 3 to 6, inclusive, are curves illustrating the manner of operation of my invention under various conditions, as will be more clearly pointed out in the following description.

It is common practice to utilize as a source of frequencies containing a plurality of harmonics, various types of oscillation generators. In choosing a generator for this purpose, it is desirable to pick one of that type which will generate a wave approaching that of a square or substantially square top wave. It has been found that such a wave contains a practically unbroken and unlimited series of harmonics.

An oscillation generator having this characteristic to a marked degree is one commonly termed a "multivibrator". In Figs. 1 and 2 of the accompanying drawings, I have illustrated oscillation generators of the multivibrator type. A generator of this type comprises a pair of thermionic devices 1 and 3 coupled together by capacities and resistances and so arranged as to produce alternate discharges spontaneously. In Figs. 1 and 2, wherein I have disclosed an oscillation generator of this type, it will be noted that the circuits associated with the thermionic devices are symmetrically arranged with regard to each other. The grid circuit of each tube comprises a resistor 5 or 7 connected between the filament and grid of its respective tube. The plate circuits of the tubes also comprise resistors 9 and 11, both connected between the plates of their respective tubes and the positive terminal of a common plate potential supply unit 13, through a coil 15, the negative terminal of the plate supply unit being connected to the common grounded filament connection. Between the plate of each tube and the grid of the other, there is connected a variable condenser 4 or 6, respectively, by means of which changes may be made in the adjustment of the circuits.

The coupling system shown by coils 15 and 19 might equally well be any other coupling device and might be connected in any manner which would introduce the coupling frequency to both tubes symmetrically. One other manner consists in inserting such a system of coupling coils between the grid resistors and the filament.

Ordinarily, it would appear in a system embodying symmetrically arranged circuits as shown, that the circuits would be balanced and, therefore, a stable condition would exist therein. While this condition should exist theoretically, such a condition is not maintained by reason of the fact that various unbalancing influences prevail which cause an arrangement of the type disclosed to be a most unstable one. Slight differences in the corresponding elements of the system, the effect of sound waves impinging on the tubes, etc., all tend to upset the balance of the system.

Assume that some such disturbing influence causes a slight increase in the plate current of tube 1. This will produce an increase in the potential drop across the resistor 9 in the plate circuit of that tube which will result in a reduction of the plate voltage on the anode of the tube 1. This change of potential acting through the variable condenser 6 connecting the plate of the tube 1 with the grid of the other tube 3, will reduce the voltage on the grid of the second tube 3. This decrease of potential will necessarily result in a corresponding decrease in the plate current of this second tube, the drop in plate current being many times greater than the slight increase of current in the plate circuit of the first tube. The reduced current will decrease the potential drop across the resistor 11 in the plate circuit of the second tube 3, thereby increasing the potential on the plate of said tube. This increase in plate potential on said tube 3 acting through the variable condenser 4 located between the plate of the tube 3 and the grid of the tube 1 will serve to further increase the potential on the grid of the first tube. Accordingly, this increase will still further increase the plate current of the first tube 1 with a further decrease in the grid potential of the second tube 3, etc. The above cyclic phenomenon constitutes a transient condition which will continue until the potential on the grid of the second tube falls below that point known as the cut-off point of the tube, at which point the current in the plate circuit of that tube will have been reduced to zero value, and therefore, will discontinue to flow.

The condensers 4 and 6, by this time, have become charged and are in an unstable condition. With no current serving to maintain the charges on the condensers, at this point, they will accordingly discharge through resistors 5 and 7 or 9 and 11, respectively. During the discharge period, the potential on the grid of the second tube 3 will build up to a point where plate current in that tube will again begin to flow, at which time another transient condition will be set up, but in a direction which will be opposite to that transient described above. These alternate discharges between the tubes of the system will continue so long as energy is supplied from the source of plate potential supply and the A battery supply. The frequency of these discharges may be controlled by varying the values of the condensers and/or the resistors.

In utilizing any oscillation generator as a source of high frequencies, it is very desirable, where accuracy is necessary, to control the fundamental frequency of the generator to prevent it from shifting in frequency from that of its designed value to a value closely adjacent thereto. To obtain this result, it is common practice to employ a control frequency wave which is impressed upon the circuit of the oscillation generator, the frequency of the control wave bearing an harmonic relationship to the fundamental frequency of the generator.

In the methods and means commonly resorted to, according to the prior art, if the frequency of the generator should, for any reason, shift nearly to an adjacent sub-harmonic of the control frequency, the tendency would exist, whereby the control frequency would now function to alter and maintain the fundamental frequency of generator at the adjacent sub-harmonic. This, of course, is not the result desired, and by my invention, I have provided means whereby the frequency of the generator may shift between wider limits without being pulled out of step with its original fundamental frequency as described above. More specifically, according to my invention, the frequency of the generator will have to shift twice as far as heretofore, before the control frequency will tend to pull it out of its original value.

Referring more particularly to the drawings, I have disclosed two modifications whereby the above results may be obtained. In the modifications, I have illustrated the oscillation generator in combination with a source of control frequencies, the particular results obtained arising out of the manner in which I have coupled the control frequency source to the oscillation generator.

According to the modification disclosed in Fig. 1, I connect the positive terminal of the plate supply source to the mid-point 17, of the coil 15 which is connected in the plate circuit of the tubes. The output circuit 19 of the control frequency source 21 is coupled to this coil 15 as clearly illustrated in the circuit disclosed and described by me. The control frequency potential induced in the coil of the oscillation generator will, by reason of the described connection, be impressed upon the anodes of the thermionic devices 1 and 3 equally or substantially so, but in opposite phase relationship.

The operation of the system, according to this modification may be clearly explained in conjunction with Figs. 3 and 4.

Referring more particularly to Fig. 3, I have therein represented a plurality of cycles of the oscillation generator frequency in combination with a control frequency. For simplicity of explanation, I have illustrated substantially ideal conditions of wave form. The upper half of the figure represents the transient effects existing in one tube and the lower half representing the operation of the second tube.

In the figure, three curves are shown for each tube. Curve 23 represents the current flow in a multivibrator circuit under substantially ideal conditions, curve 25 the control frequency impressed upon the multivibrator circuit and curve 27, the resultant characteristics of the current in the multivibrator circuit as altered by the impressed control frequency. The broken line 29 indicates the cut-off point on the tubes in the multivibrator circuit. The cut-off point is that value of grid potential which reduces the plate current to zero. When the grid potential of one tube passes above the cut-off point, a discharge takes place through the two tubes of the circuit.

The circuit disclosed in Fig. 1 is designed to provide control of the fundamental frequency of the oscillator at odd sub-harmonics only of the control frequency. This result is obtained by reason of the particular coupling connection to the control frequency source. As noted above, the control frequency potentials will be impressed upon the tubes of the oscillator equally but in opposite phase relationship. In Fig. 3, curves 25 represent control frequency as impressed upon the tubes of the oscillator and in this particular case, the control frequency bears an odd harmonic relationship to the fundamental frequency of the oscillator and is shown impressed equally but in opposite phase relationship upon the tubes of the oscillator. Outside of the fact that the cut-off point is reached sooner than when the control frequency is not applied, no change occurs in the frequency relationship existing between the fundamental of the oscillator and that of the control frequency, and the oscillator will, therefore, continue to oscillate at its designed frequency.

Should the fundamental frequency of the vibrator or oscillator tend to shift for any reason to a value which bears an even sub-harmonic relationship to the impressed control frequency, an unstable condition will develop and the fundamental frequency of the oscillator will be brought back to its odd-sub-harmonic relationship. This unstable condition and the manner in which the control frequency functions to bring the frequency of the oscillator back to its odd-sub-harmonic value is clearly illustrated in Fig. 4. In Fig. 4, therefore, it has been assumed that the frequency of the oscillator had shifted to such a value as to bear an even sub-harmonic relationship to the control frequency which control frequency in actual practice is maintained constant by means of a crystal or tuning fork control. It will be seen that the even-sub-harmonic relationship cannot exist for any appreciable length of time, for within each half cycle, the phase of the oscillator will be shifted enough to make the length of the half cycle equivalent to an adjacent odd-sub-harmonic of the control frequency.

It will be apparent, therefore, in a circuit as disclosed in Fig. 1, that the frequency of the oscillator will be controlled at odd-sub-harmonic frequencies only of the control frequency. The control frequency, consequently, will function as a control throughout a frequency range which will be substantially twice as great as in similar circuits of the prior art as known by me. In other words, the natural frequency of the oscillator will have to shift twice as far as previously necessary, before it will be beyond the power of the control frequency to bring it back to its original frequency.

In Fig. 2, the coupling of the control frequency source to that of the oscillator is of such a character that the frequency of the oscillator can be controlled at even-sub-harmonics only of the control frequency. The operation of this circuit is clearly illustrated by means of the curves of Figs. 5 and 6 bearing reference numerals similar to those applied to the curves of Figs. 3 and 4.

Fig. 5 represents a condition wherein the frequency of the oscillator bears an even sub-harmonic relationship to that of the control frequency in a circuit such as shown in Fig. 2. As in the circuit of Fig. 1 under the condition exemplified in Fig. 3, the only effect of the control frequency upon the fundamental frequency of the oscillator is to shift the time at which cut-off occurs. Outside of that, no material changes are produced. The frequency of the oscillator is maintained, and should it for any reason tend to shift from its designed frequency, the control frequency will function to bring it back to its normal frequency. The manner in which this controlling function operates is illustrated by means of the curves of Fig. 6 where an extreme case is taken as an example. The condition illustrated in Fig. 6 exists when the frequency of the oscillator has, for some uncontrollable reason, shifted to an adjacent sub-harmonic which bears an odd sub-harmonic relationship to the control frequency instead of an even sub-harmonic. By reason of the particular coupling employed in the system of Fig. 2, the control frequency will be applied equally and in phase to both tubes of the oscillator, as clearly illustrated in both Figs. 5 and 6.

The frequency of the oscillator as represented by curve **23** of Fig. 6 will be changed to a frequency corresponding to curve **27**. When this new frequency is compared to that of the control frequency, it will be found that it bears an even sub-harmonic relationship to that of the control frequency. In order, therefore, for the fundamental frequency of the oscillator to be pulled out of its designed frequency, it will have to shift somewhere in the neighborhood of the next even sub-harmonic which, of course, means that the shift must be approximately twice as much as in former similar systems wherein the frequency of the oscillator would be pulled into its closest sub-harmonic frequency whether that frequency be an even or odd sub-harmonic.

In Figs. 7 and 8, I have illustrated my invention as applied to oscillators of the neon tube relaxation type. As oscillator of this type comprises one or more neon tubes shunted by a capacity in parallel with a source of potential. The operation of an oscillator of this type may theoretically be explained as follows. The source of potential sends a charging current through a limiting resistor, to both the neon tube and the capacity shunting it. When the potential built up across the tube reaches the break-down value of the tube, the tube breaks down providing a conductive discharge path for the capacity which, accordingly, rapidly discharges its absorbed energy through the tube. The potential across the tube thereby is reduced sufficiently to bring it back to its initial non-operating condition, ready for another charge whereupon the cycle is automatically repeated.

The particular oscillator of this type disclosed by me comprises a pair of neon tubes **31** connected in series across a source of potential **33** and a current limiting resistor **35**. Capacities **37**, preferably similar in characteristics, are shunted across each tube respectively. The source of potential **33** should be of such value as to produce break-down in the two tubes in series. When the breakdown potential is reached, the capacities **37**, which have been charged to the break-down potential, will discharge through their respective tubes in the manner described above. The periodic charge and discharge of the condensers will produce an oscillatory current of a definite frequency, depending upon the value of the constants of the system.

In the particular embodiment disclosed in Fig. 7, a coil **39** which is substantially evenly divided between the two condenser circuits is inductively coupled to the coil **41**, which coil comprises the output of a control frequency source. The control frequency potential will, therefore, affect each tube simultaneously and similarly and, as in the case of the multivibrator circuit of Fig. 2, wherein the both tubes were affected in the same manner and simultaneously so the control frequency will function to control the fundamental frequency of the oscillator at even sub-harmonics only of the control frequency.

In the modification disclosed in Fig. 8, the coil **39** is inserted in that portion of the system which is common to the both condenser circuits, and is coupled to the coil **41** whereby the control frequency may be impressed thereon. With the coil **39** in the location designated, the control frequency will affect the tubes in a manner similar to that described in regard to the circuit of Fig. 1; that is, the tubes will be affected equally, but the impressed potentials will be in opposite phase relationship with regard to the potential impressed upon the tubes by the source **33**. Consequently, in this embodiment of my invention, the control frequency will function to control the fundamental of the oscillator at odd sub-harmonics only of the control frequency.

Throughout the specification, I have used the term "frequency" in a generic manner as applied to current or potential at that frequency.

Since, according to my invention, the frequency of the generator may be controlled, at either the odd or the even sub-harmonics only, according to the circuit used, I have referred to the even or odd harmonics as constituting alternate harmonics and have so expressed them in the claims.

While I have disclosed my invention in great detail, it will be apparent that various changes might be made within the contemplated scope of my invention, and I, therefore, do not desire to be limited to the specific details described, except insofar as is necessitated by the prior art and by the appended claims.

I claim as my invention:

1. In combination a control frequency source, means for producing an oscillatory condition comprising an oscillator of the multi-vibrator type including a pair of discharge devices, the frequency of said oscillatory condition bearing a definite sub-harmonic relationship to that of the control frequency, and means for impressing upon

each of said discharge devices an alternating potential derived from said control source, said potentials being 180 degrees out of phase with each other.

2. In combination, a pair of electron discharge devices, each having an anode, a grid and a cathode, inductance connecting said anodes, a source of energy connected between said cathodes and substantially the mid-point of said inductance, a capacitor connected to each of said anodes and a separate impedance connected between each of said capacitors and said cathodes, a connection from the grid of each of said discharge devices to the junction of that capacitor and its associated impedance which is connected to the anode of the other discharge device, and means for impressing an alternating electromotive force across the inductance connecting said anodes.

3. In combination, a pair of electron discharge devices, each having an anode, a grid and a cathode, inductance connecting said anodes, a source of direct current energy connected between said cathodes and substantially the midpoint of said inductance, a capacitor connected to each of said anodes and a separate impedance connected between each of said capacitors and said cathodes, a connection from the grid of each of said discharge devices to the junction of that capacitor and its associated impedance which is connected to the anode of the other discharge device, and means for impressing an alternating electromotive force across the inductance connecting said anodes.

4. In combination, a pair of electron discharge devices, each having an anode, a grid and a cathode, inductance connecting said anodes through resistors individual to said anodes, a source of energy connected between said cathodes and substantially the mid-point of said inductance, a capacitor connected to each of said anodes and a separate impedance connected between each of said capacitors and said cathodes, a connection from the grid of each of said discharge devices to the junction of that capacitor and its associated impedance which is connected to the anode of the other discharge device, and means for impressing an alternating electromotive force across the inductance connecting said anodes.

VICTOR J. ANDREW.