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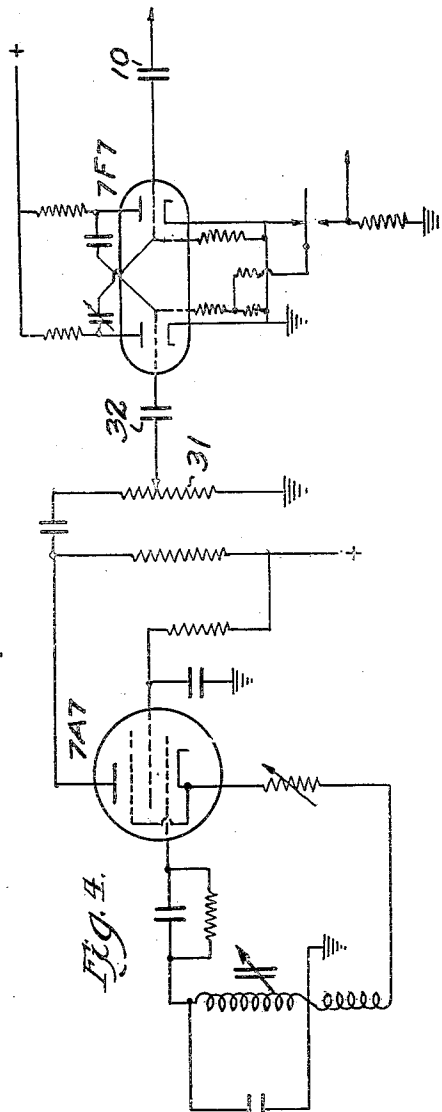
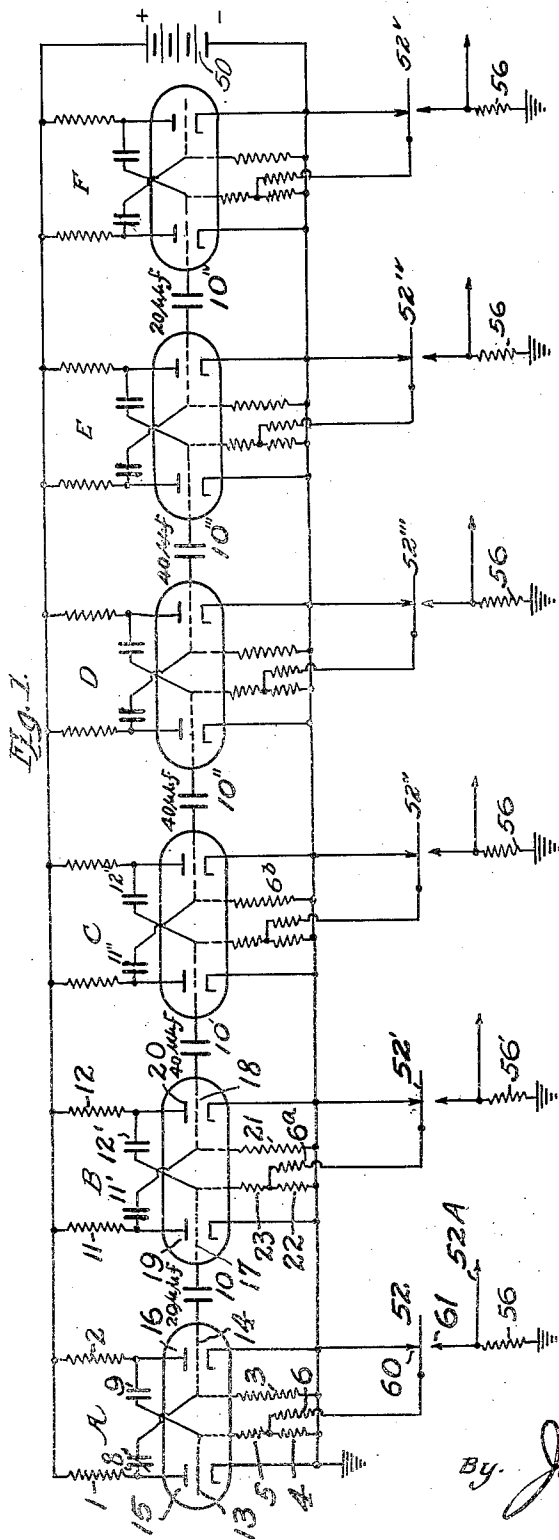
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2,410,883

FREQUENCY GENERATING SYSTEM

Filed Sept. 17, 1943

3 Sheets-Sheet 1



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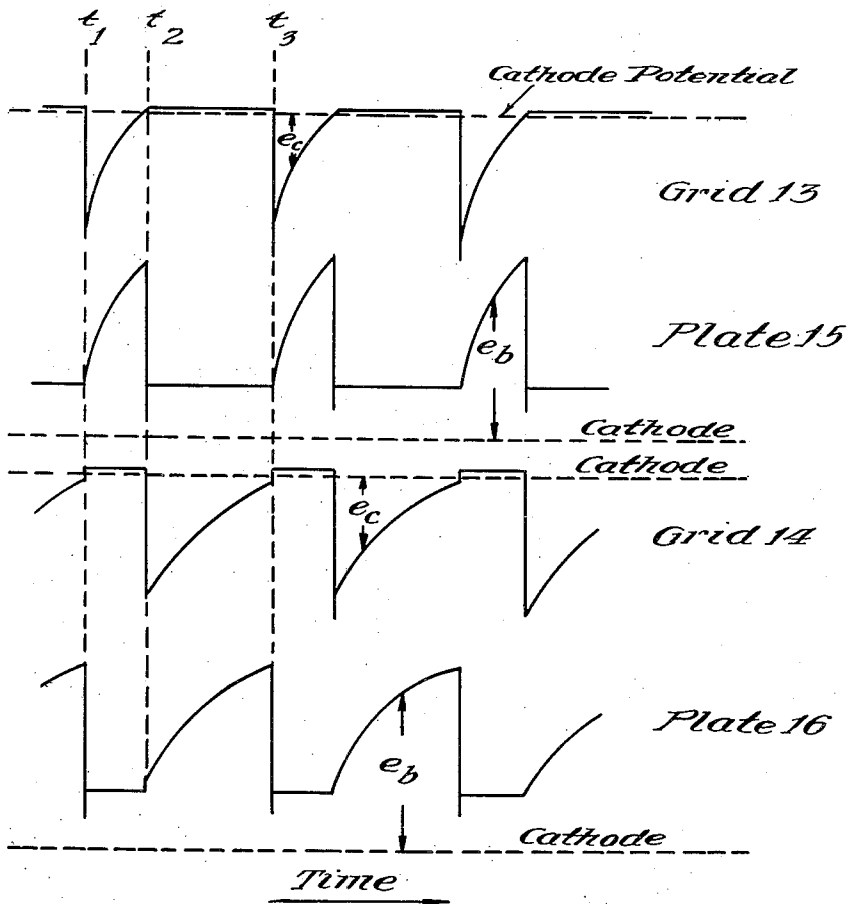
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Fig. 2.



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3 Sheets-Sheet 3

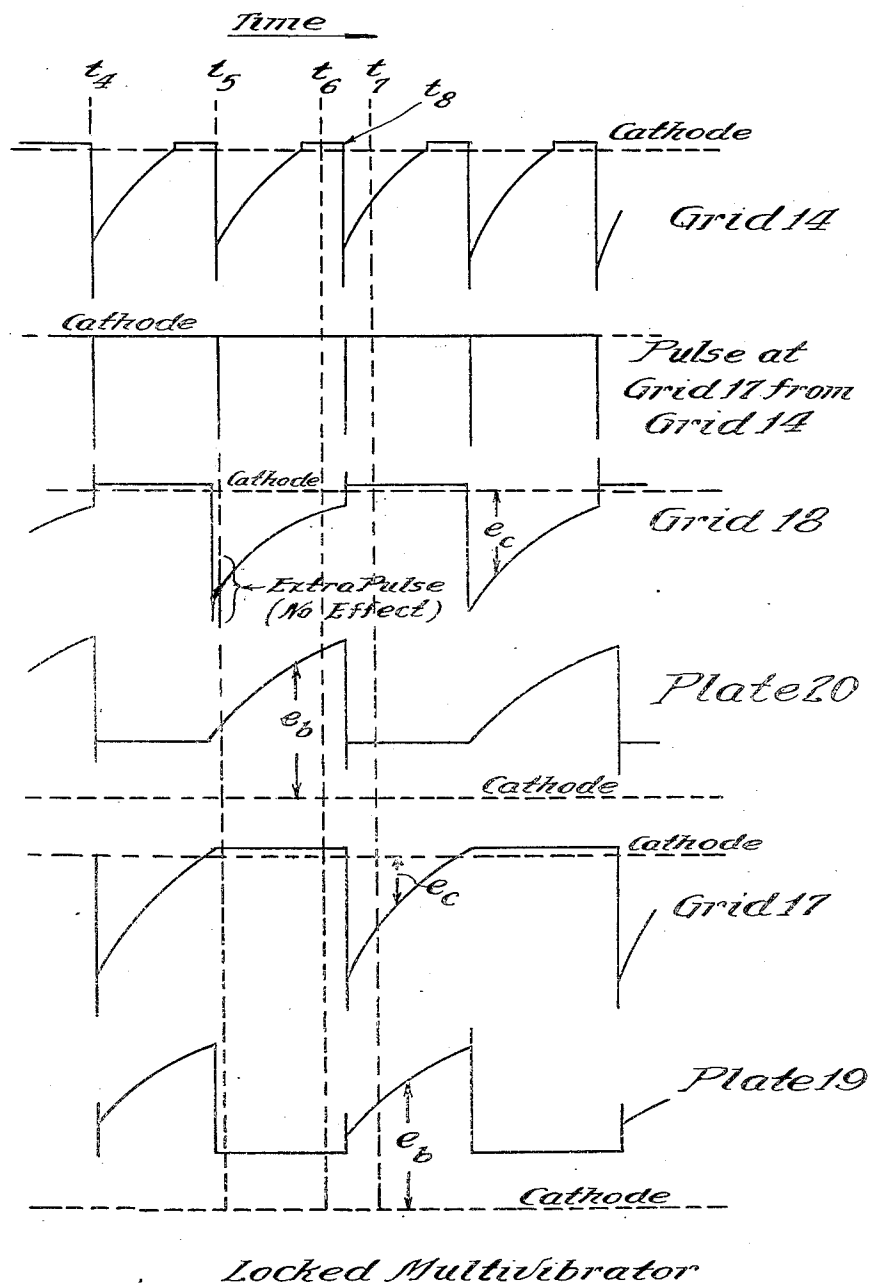


Fig. 3.

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UNITED STATES PATENT OFFICE

2,410,883

FREQUENCY GENERATING SYSTEM

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Application September 17, 1943, Serial No. 502,762

6 Claims. (Cl. 250—36)

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This invention relates to frequency generators, the main objects of which are, as follows:

(1) The provision of a submultiple frequency generating system in which multivibrator stages are connected in cascade to produce tone frequencies which are accurately at octave separation.

(2) The provision of a highly effective and dependable capacitance potential dividing system in the cascade of multivibrator stages for insuring production of a sharp controlling pulse waveform into the multivibrator stage being locked.

(3) The provision of coupling means between the respective stages in a cascade of stages for reducing to a negligible amount feedback from a lower to a higher frequency stage.

(4) The provision of a frequency generating system in which the individual multivibrator stages, such as Radio Corporation of America 7F7 tubes or their equivalent, oscillate at submultiple frequencies and are productive of output waveforms which are rich in harmonics.

(5) The provision of capacitive couplings between the respective stages of a chain of similar stages, the capacity of each of which is small and precalculated to insure absolute locking of said stages.

(6) The provision of a greatly simplified frequency generating system and means therein for insuring correct electrical coordination of the elements and components.

(7) The provision of a highly dependable method by which improved locking and stabilization of coupled oscillators is effected, one such oscillator producing a sinusoidal waveform of locking voltage, which is used at the other oscillator, in a new and improved manner to control the frequency of oscillation of the other oscillator.

(8) The provision in a chain of oscillators, respectively tuned to oscillate exactly according to a predetermined pitch relation of musical tones of means actuable from a single one of said oscillators for causing like readjustment in tuning of all oscillators in said chain.

(9) The provision of a system wherein the electrical constants of the system, as a whole, are so correctly calculated and electrically interrelated that in the event that in the regular course of events it becomes necessary to substitute a new frequency generating stage for one that has outlived its usefulness, this can be done quickly and without any significant effect upon the system and without impairing operation of the system.

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Other objects and advantages will appear from the following description and of the drawings, in which:

Figure 1 is a schematic view of our multivibrator submultiple frequency generating system.

Figure 2 is a view illustrating the potential waveforms of the various points in an unsymmetrical multivibrator operating at its own natural frequency, which is essentially the condition of the first stage shown at Figure 1.

Figure 3 is a view illustrating the potential waveforms of a multivibrator which is locked by another multivibrator of twice the frequency, and

Figure 4 is a schematic view showing a modified form of our invention.

In carrying the invention into practice six multivibrator stages A, B, C, D, E and F, connected in cascade are shown, such for example that the frequency of oscillation of stage B is the octave of the frequency of oscillation of stage A. Each successive stage oscillates at a frequency which is the octave of the next preceding stage. In like manner, all stages below stage B will similarly oscillate at a frequency which is one-half the frequency of the preceding stage in said cascade.

Each of the multivibrator stages includes a twin triode, including two sets of electrodes consisting of a cathode, control grid, and plate. The multivibrator A, for example, includes two sets of associated electrodes including grid 13 and plate 15, and grid 14 and plate 16. The input circuit of the twin triodes are completed through high resistance paths of different effective resistances, constituted in the case of control grid 13, and its associated cathode by the resistances 4 and 5, and in the case of the control grid 14 and its associated cathode, by resistances 3. The output circuit of the twin triode includes resistances 1 and 2 leading from plates 15 and 16, respectively, with variable condenser 8 connected between control grid 14 and a point intermediate resistances 1 and plate electrode 15, and fixed condenser 9, connected between control grid 13 and a point intermediate plate 15 and resistance 12. The dropping resistance 6 is connected to a point intermediate resistances 4 and 5 and leads to the playing key 52, movable between contacts 60 and 61. Contact 60 returns to the common input circuit bus of the several multivibrators, while contact 61 leads through grid biasing resistance 56 to ground, thus returning to the common cathode bus.

The resistive multivibrator circuit constituting stage A is coupled to the succeeding stage B

through the coupling capacitance 10 having the value in the circuit illustrated of 20 mmf. to the control grid 17 of one set of the electrodes of the twin triode in multivibrator stage B. The twin triode in multivibrator stage B includes two sets of electrodes constituted by control grid 17 and plate 19 with an associated cathode, and a control grid 18 and plate 20, with an associated cathode. The control grid 17, which connects to the coupled capacitance 10 also completes an input circuit through resistors 23 and 22, returning to the associated cathode. The input circuit for the opposite sets of electrodes is completed from control grid 18 through resistance 21, returning to the associated cathode. The resistive paths are of different values as will be hereinafter explained. Dropping resistance 6^a connects to high intermediate resistances 23 and 22 and leads to the playing key 52 with which is associated the resistance 55'.

The output circuit of the sets of electrodes constituting the twin triode of stage B include resistances 11 and 12, connected in each of the plate supply leads extends to the common plate supply bus. Fixed condenser 11' is connected to a point intermediate resistance 11 and plate 19 to control grid 18, while fixed condenser 12' is connected to a point intermediate resistance 12 and plate 20, and to the control grid 17. The control grid 18 is connected through coupling capacitance 10' which is of 40 mmf. to the control grid of the first set of electrodes of the twin triode constituting multivibrator stage C.

The circuits for the multivibrator stage C are similar to those described with respect to stages A and B except that the capacity values of condensers 11'' and 12'' are of greater value than the corresponding condensers in the preceding stages, as will be hereinafter explained in detail. The biasing circuit is represented as including playing key 52'' connected to resistance 6^b with an intermediate point in the low resistance grid circuit. The contact system for the playing key is arranged in a manner similar to that hereinbefore described, where one of the contacts leads to bias resistor 56'', returning through ground to the common cathode bus.

In a similar manner I arrange multivibrator stages D, E, and F, coupled through condensers 10'', 10''' and 10^{iv} of 40 mmf., 40 mmf., and 20 mmf., respectively. The biasing potential on the grid circuits of each of the multivibrator stages D, E, and F is similarly controlled through playing key 52'', 52^{iv}, and 52^v, respectively. In each instance it will be observed that the playing key is connected to an intermediate point in the low resistive path of the unsymmetrical grid circuits of the multivibrator. The circuits heretofore described are also contained in the modified form of my invention, illustrated in Fig. 4, in which the separate oscillator tube 7A7 is coupled through output resistance 31 and the coupling capacity 32 to the twin triode 7F7 corresponding to the tube of stage A illustrated in Fig. 1.

It further will suffice to say that when moving key switch 52 associated with said stage A off of contact 60 which is at ground potential, to and onto contact 61 when the key is depressed, the output waveform of grid voltage from said stage is taken off from a high potential dividing and dropping resistance 6, the latter connected between the series resistances 4 and 5, as shown. When the circuit is thus completed, said waveform of voltage is impressed upon a respective circuit 52A connected, as shown, to the grid bias

resistance 55. Similarly, upon depressing playing-key 52' associated with multivibrator stage B, the waveform of voltage will be taken off of said stage through the potential dividing and dropping resistance 6^a which is connected intermediate the series resistances 22 and 23, the frequency of said waveform of voltage being a sub-multiple of the waveform of voltage taken off of said stage A.

As the respective multivibrator stages are identical in all respects as regards the electrical values of resistances employed, it is important to note that these resistances are high, in order that the average current drain upon any individual stage is the same and so slight as to insure prolonging the life thereof. For example, all of the plate resistances 1, 2, 11 and 12, etc., are each thereof 1 megohm and therefore symmetrical while the resistances in the grid circuits are unsymmetrical. Various and extensive experiments seem clearly to indicate that by making the grid resistances unsymmetrical, improved locking results are obtained, but, and in this respect, and as will appear presently, this may be modified without change in the functional result which these resistances contribute to the utility of our invention.

Referring to stage A in the dividing system shown at Figure 1, resistance 4 is 10,000 ohms; resistance 5, 300,000 ohms; resistance 3, 1 megohm, and dropping resistance 6, 50,000 ohms, thereby providing an input impedance to the work circuit of approximately 1000 ohms which is sufficiently low to prevent distortion of the waveform of voltage being transmitted in response to close circuiting of switch 52. It is not amiss to say that distortion, in the sense employed herein has reference to changes in the waveform of voltages which changes obviously would be produced by the tube itself, its operating bias, plate supply, resistances in the plate circuits of the tube, etc., in the absence of the resistive circuits comprising our improved dividing system.

With the above relative values of resistances, experiments show that the output voltage of the fundamental component measured across high resistance 4 is of the order of magnitude of 0.1 volt and is relatively independent of frequency, the harmonics of the individual note tapering approximately as follows:

Harmonics	Output (percent of fundamental)
1.....	100
2.....	70
3.....	50
4.....	39
5.....	31
6.....	26
7.....	23
8.....	20
9.....	18
10.....	16
Etc.....	

While we have shown and described unsymmetrical grid circuits functioning in the manner aforesaid, it shall be noted that highly satisfactory results are had with grid resistances providing a symmetrical arrangement in which resistances 3 and 21, etc., are approximately 1/2 megohm. The arrangement shown herein will therefore be considered merely as one optional method of obtaining substantially similar functional results, namely, to confine the output voltage from any multivibrator stage to only a small

fraction of the total produced voltage and thereby render the input impedance of said work circuit sufficiently low to prevent distortion and change in frequency of the waveform of voltage, and also to insure that the average plate and grid currents per individual multivibrator stage is so low that neither stage nor component is abused, thereby increasing the operating life of said stages and reducing the cost of operation of the instrument as a whole.

To set the multivibrator stages of a common chain or cascade of stages at their proper frequency, capacitances 8 and 9 of the first stage A, Figure 1, are selected on the basis of an experimental curve of capacitance vs. frequency. This curve may be expressed by a simple equation where the frequency is inversely proportional to the capacitance. That is, $f=K/C$ where the constant K is determined by the tube itself, its circuits, resistances and operating voltages. The capacitances used at the locked or lower frequency stages are somewhat higher, say 25% or may even be higher as the locking pulse increases in magnitude as the stages progress toward the lower frequency end of the cascade.

It follows, from what has been said, that in the entire chain or cascade of multivibrator stages there is but one adjustable capacitance, this being condenser 8 in the circuit of stage A and that this may comprise any well known trimmer or padding condenser. All others of the condensers employed may be fixed and can be of any well known commercial type, but preferably of the type employing mica dielectrics.

In Figure 1, the fixed capacitances 11' and 12' in the grid to plate circuits of stage B are functionally comparable to capacitances 8 and 9 in the corresponding circuits of stage A. The plate resistances 11 and 12 are comparable to resistances 1 and 2, stage A and the resistances 6^a, 21, 22 and 23 are comparable to corresponding resistances in the grid to ground circuits of said stage A.

Typical operating voltages of multivibrator A are shown at Figure 2. This may be considered as typical also of multivibrator B if it were not locked by multivibrator A. It is seen that one triode at a time is conducting and while that triode is conducting its operating voltages are relatively constant. The transfer of conduction from one triode to the other is done during a very small portion of the cycle.

Upon referring to Figures 2 and 3, the operating sequence of multivibrator A is as follows: At time t_1 grid 14 has just gone slightly positive. This causes current to flow in plate resistance 2 and plate 15 consequently drops suddenly. The sudden drop of plate 16 throws grid 13 via capacitance 9 negative, thereby shutting off the plate current in grid 13. After this quick transfer, capacitance 9 discharges through the grid resistance, chiefly 5, and capacitance 8 charges through resistance 1. During this portion of the cycle, between times t_1 and t_2 , grid resistance 3 and plate resistance 2 have but a minor effect on the charge or discharge time as grid 14 and plate 16 are essentially fixed in potential. At time t_2 grid 13 has risen sufficiently to cause grid 14 to become conductive whence the cycle is reversed. The discharge time of capacitance 8 through grid resistance 3 is longer because of the higher value of resistance 3. Hence a longer period between t_2 and t_3 . During this period capacitance 9 charges through the plate resistance 2. The exact time at which transfer occurs depends upon

the time to charge the capacitances associated with the plate resistances as well as upon the discharge time associated with the grid resistances, and also, of course, upon the tube characteristics and supply voltages.

Multivibrator B is locked by a pulse through capacitance 10 from multivibrator A. The manner in which this is accomplished is evident upon examining the wave forms shown in Figure 3. Here the grid voltage from grid 14, multivibrator A, is redrawn above the voltages of multivibrator B because the controlling voltage is taken from grid 14. The transient dip in grid 14 occurs in such a short time that the pulse can be transmitted to grid 17, multivibrator B, through a very small capacitance 10. The pulses transmitted are shown in the figure. A potential divider is formed between grid 14, grid 17, and the cathode by means of coupling capacitance 10 and the tube input capacitance and resistance. A coupling capacitance of a value ranging between 20 and 40 micro-microfarads was found adequate for the tube used, a 7F7 duo triode. The coupling capacitance 10 is relatively independent of the frequency concerned because the hair-line pulse occurs during approximately the same interval, regardless of the charge and discharge time for capacitances 11' and 12'. Hence it has been found that the coupling capacitance 10 can be the same whether the frequency is at the bottom or the top of the audio range used. This is contrary to heretofore known coupling systems where the object has always been to increase the capacitance as the frequency lowers in order to maintain more or less constant reactance. In our system the capacitance must remain small. Should it be too large the locked unit B will tend to follow A at the same frequency. Should the coupler be too small, on the other hand, then the locking range is reduced.

The tripping is accomplished as follows: The negative pulse on grid 17 causes a positive pulse on grid 18. This is because the negative pulse on grid 17, assuming the triode associated with 17 is conducting, causes a momentary cut-off so that plate 19 starts to rise abruptly. But this causes grid 18 to rise via the capacitance 11' and hence the righthand triode of B conducts.

The timing required is shown at Figure 3. The positive pulse on grid 18 must occur before capacitance 11 has discharged, that is, before the grid 18 becomes sufficiently above cut-off, or even positive, to cause the righthand triode to become conductive. In fact, the natural frequency must always be equal to, or lower than the locked frequency. In more detail, at time t_4 grid 14 shoots negative, so also does grid 17. This causes plate 19 to rise and also grid 18. If the pulse is great enough, tripping occurs. The next following pulse of grid 14 has no effect except to introduce a pulse such as that occurring at time t_5 . The lefthand triode of unit B seems to follow its own time constants, as is evident by the potential curve of grid 17. Should the frequency of the control tube, A, be increased, then tripping would occur sooner at a time, say t_6 . Should the frequency of A be lowered, then tripping would occur later at some time as indicated by t_7 . While the period between t_4 and t_5 would alter some with changes in frequency of the control tube, most of the altering is done during the time the righthand tube is non-conducting, time from t_5 to t_8 . The longer time constant associated with the higher grid resistance 21 and capacitance 11 permits a greater portion of the total cycle to

be under the influence of the locking pulse. This seems to account for the somewhat better control gained with an unsymmetrical circuit. Other unbalanced arrangements are possible, of course, such as increasing capacitance 11' and decreasing resistance 21, but the arrangement explained is simpler for construction purposes, where it is easier to employ like capacitances per multivibrator.

The total range in locking extended by test over nearly an octave, from the lowest unlocked to the highest unlocked position. Upon unlocking, a slight return in frequency caused the tube concerned to lock again. In this system, as mentioned, locking does not occur unless the natural frequency is lower than the required locked frequency. While locking may be accomplished at any integral multiple of the locking frequency, up to a high ratio, stress is placed here on sub-octave locking as that is the chief function for which the system is designed.

Because the transient of the lower stage occurs simultaneously with every other transient in the upper locking stage, the feed-back is small. Under test the feed-back has been found to be less than one percent. In this circuit, the use of a resistance in series with the coupling capacitance not only decreased the locking effect, but also greatly increased the feed-back.

We particularly stress the fact that all plate resistances are each thereof high and the same as the grid resistances in the right hand triodes of the respective stages, namely, 1 megohm and that resistances 4, 5 and 6 and corresponding resistances in the grid and output circuits of the left hand triodes in Figure 1 are unequal, resistance 4 being 10,000 ohms, resistance 5 being 300,000 ohms and resistance 6 being 50,000 ohms.

We stress also the importance of substantially like, small coupling capacitances between the respective stages and in the cascade herein shown the first and last capacitances are each 20 micromicrofarads and the intermediate capacitances, each 40 micromicrofarads.

The grid biasing resistance 56 for each stage in the cascade is considerably lower than the aforementioned dropping resistance, say, between 1,000 and 10,000 ohms.

The capacitances in the plate to grid circuits are as follows: stage A, 125 micromicrofarads, stage B, 300 micromicrofarads; stage C, 680 micromicrofarads; stage D, 1,500 micromicrofarads, stage E, 3,300 micromicrofarads and stage F, 9,000 micromicrofarads.

From the above it is observed that only the first of the plate to grid capacitances is adjustable and that the capacitances in the plate and grid circuits of each individual stage are of the same value but different from the values of the capacitances in any other stage of said cascade of stages.

Referring again to the coupling capacitances between the respective multivibrator stages it is important to note that as the first and last stages have different output and/or input capacitances, the coupling condensers associated therewith are lower than the capacitances in the intermediate couplings. A capacitance potential divider system is thus formed between the output grid, the coupler and wiring capacitance of the locked stage, the same responding to the higher harmonics and insuring production of a sharp pulse wave which is impressed on the grid of the triode of said stage. It should be borne in mind that if the coupling condensers are too high, the stage

will lock with the stage above it and if too low, the frequency tolerance will be poor. A sub-multiple generating system as herein disclosed is designed primarily for the production of alternating voltages at the tone frequencies of different notes of the musical scale. It follows from this that the operation of a cascade of multivibrators must be so dependable at all times, that there shall be no change in the octave relation of the respective stages.

In an application of Merwin L. Larsen, Ser. No. 554,837, filed September 19, 1944, twelve similar cascades of multivibrators are employed for the production of electric waves of the tone frequencies of the notes of the even tempered musical scale, such that a cascade of multivibrators as shown and described herein will produce output wave forms having the tone frequencies of all C notes, ranging from $C_2=65.4$ cycles per second to $C^3=2093$ cycles per second.

Figure 4 shows a multivibrator submultiple divider system under the control of a separate oscillator for cases where more precise control is desired. A conventional electron-coupled oscillator such as a 7A7 vacuum tube is shown as an example of a moderately stable oscillator. A sine wave may be produced at the adjustable output 31 by increasing the feedback resistance 30 until oscillations nearly cease. The multivibrator to be locked may be considered the same as multivibrator A of Figure 1. An optimum set of values for locking can be found by adjusting the voltage at 31 and the capacitance 32 which couples to the multivibrator. As an example for locking between a range of 2000 cycles and 4000 cycles, a typical set of values for either same-frequency locking or sub-octave locking was found to be 10 volts and 100 micro-microfarads. In the system the range also was very nearly an octave.

When locking with a sine wave the natural frequency of the multivibrator to be locked lies approximately midway between the upper and lower limits when locked. This is because both positive and negative portions of the locking cycle act upon the input grid. The positive portion will tend to cause the lefthand triode to trip while the negative portion will tend to cause the righthand triode to trip.

These methods of locking are considered practical and significant because they are simple in construction and reliable in operation. When using the stable master control, as shown in Figure 4, for example, tests show that locking throughout a 6-stage system is maintained even though the normal plate supply of 150 volts is varied from 20 to over 350 volts. Very wide variations in heater current are also allowable.

In using the system without the separate master, changes in voltage produce changes in frequency, as the whole system is locked together. Frequency rises as the voltage lowers and conversely. However, locking is insured even though the voltage changes made are greater than those mentioned when using a master oscillator.

As can be inferred from the waveforms of the output grid, the output is rich in harmonics. The taper as the harmonics increase is somewhat less than that of a saw-tooth wave. For those tested the tenth harmonic had an amplitude of between 15 and 20 percent of the fundamental, whereas for a saw-tooth wave the tenth harmonic would have an amplitude of 10 percent of the fundamental. The taper was smooth. This gives an excellent source for tone production where natural harmonics are available for selective filter-

ing and mixing to produce many of the desired tone qualities.

In Figure 1, the voltage at source 50 is chosen arbitrarily, it having been found that the multivibrator stages of the respective stages will stay locked with a voltage variation of from 20 to more than 350 volts.

We particularly emphasize the feature of the invention which consists in our use of small coupling capacitances between the stages. The term "small" as used herein and applied to said coupling capacitances shall be construed to mean that said capacitances are of the order of magnitude of the input capacitances of the stages being locked. In this connection, we have taken into consideration the stage and wiring capacitance of the stage to which the locking pulse is being transmitted. Thus, in combination with small coupling capacitances the divider thus formed insures a sharp pulse waveform into the stage being locked as said divider responds only to the higher harmonics of the transmitted pulse waveform.

Having fully stated the purpose of our invention and the features constituting the gist thereof, the invention will be claimed in various combinations and subcombinations and while the invention is primarily designed, adapted and intended for use as a musical instrument employing twelve substantially identical cascades of multivibrator stages, we do not wish or intend to be limited in this respect and therefore reserve to ourselves the right to so modify the disclosed arrangement of elements as to render same useful in most any case where waveforms of voltage are desired to be produced and the frequency maintained exactly as predetermined.

When twelve substantially similar sets of multivibrators were used with the invention set forth in the aforementioned application of Merwin J. Larsen same performed in a highly dependable manner over exceptionally long operating periods of time, even in the absence of master or controlling oscillators for the first stages and without any appreciable change in the pitch at which the instrument was first tuned and that a correct octave separation of the tone frequencies likewise remained invariable for all practical purposes.

What we claim as our invention and desire to secure by Letters Patent of the United States, is:

1. In a submultiple frequency generating system, multivibrator stages connected in cascade and comprising duo-triode vacuum tubes each having cathode, control grid, and plate electrodes, with grid circuits extending between said cathodes and control grids and plate circuits connected between said cathodes and plate electrodes including a first stage operating at a given audio frequency and other stages each adapted to be locked to operate at a frequency which is a submultiple of said given frequency, each of said stages having an output circuit including a low resistance path in the grid circuit of one triode of said stage, a high resistance path in the grid circuit of the other triode thereof, a keying circuit including a movable contactor and coacting fixed contacts associated therewith, one of said fixed contacts being connected with the cathode of one of said triodes, and the other of said fixed contacts being connected to a work circuit, said movable contactor being connected with an intermediate point in the low resistance path in said first-mentioned grid circuit, and a condenser coupling said stage to the next succeeding stage

in said cascade, the coupling condensers between the different stages being substantially of the same small capacity with respect to the capacity of the grid circuits of the stages being locked.

2. In a submultiple frequency generating system, multivibrator stages connected in cascade and comprising duo-triode vacuum tubes each having cathode, control grid, and plate electrodes, with grid circuits extending between said cathodes and control grids and plate circuits connected between said cathodes and plate electrodes including a first stage operating at a given audio frequency and other stages each operating at a frequency which is a submultiple of said given frequency, each of the aforementioned stages having symmetrical resistive plate circuits and unsymmetrical resistive grid circuits, capacitative circuits for each stage such that the plate circuit of one triode of said stage is connected in series with the grid circuit of the other triode thereof, a keying circuit including a movable contactor and coacting fixed contacts associated therewith, one of said fixed contacts being connected with the cathode of one of said triodes, and the other of said fixed contacts being connected to a work circuit, said movable contactor being connected with an intermediate point in one of said unsymmetrical resistive grid circuits, and condensers coupling said stages together all of which are small relative to the capacity of the grid circuits of said stages.

3. A submultiple generator comprising a plurality of multilever stages of the duo-triode vacuum tube type, each having cathode, control grid, and plate electrodes, with grid circuits extending between said cathodes and control grids and plate circuits connected between said cathodes and plate electrodes said stages connected in cascade and including a first stage and at least a second stage; and resistive-capacitative means for fixing and maintaining the frequency of oscillation of each of said stages such that the frequency of oscillation of the second stage is a submultiple of that of said first stage, said means comprising a condenser coupling the grid circuit of one triode of the first stage with the grid circuit of one triode of said second stage for transmitting from the former to the latter a sharp controlling pulse wave; symmetrical resistive plate circuits and unsymmetrical resistive grid circuits for each of said stages, capacitances for each stage in which one each thereof connects the plate circuit of one triode of said stage in series with the grid circuit of the other triode thereof and a keying circuit including a movable contactor and coacting fixed contacts associated therewith, one of said fixed contacts being connected with the cathode of one of said triodes, and the other of said fixed contacts being connected to a work circuit, said movable contactor being connected to an intermediate point in one of said unsymmetrical resistive grid circuits.

4. A submultiple generator comprising a plurality of multivibrator stages of the duo-triode vacuum tube type, each having cathode, control grid, and plate electrodes, with grid circuits extending between said cathodes and control grids and plate circuits connected between said cathodes and plate electrodes said stages connected in cascade and including a first stage and at least a second stage; and resistive-capacitative means for fixing and maintaining the frequency of oscillation of each of said stages such that the frequency of oscillation of the second stage is a submultiple of said first stage, said means com-

prising a condenser coupling the grid circuit of one triode of the first stage with the grid circuit of one triode of said second stage for transmitting from the former to the latter a sharp controlling pulse wave; symmetrical resistive plate circuits and unsymmetrical resistive grid circuits for each of said stages, capacitances for each stage in which one each thereof connects the plate circuit of one triode of said stage in series with the grid circuit of the other triode thereof, the grid and plate capacitances for said first stage being of the same capacity and one thereof being variable and the grid and plate capacitances for the second stage being likewise of the same capacity but different from said first stage capacitances and a keying circuit including a movable contactor and coacting fixed contacts associated therewith, one of said fixed contacts being connected with the cathode of one of said triodes, and the other of said fixed contacts being connected to a work circuit, said movable contactor being connected to an intermediate point in one of said unsymmetrical resistive grid circuits.

5. A frequency divider comprising twin triode multivibrator stages each having cathode, control grid, and plate electrodes, with grid circuits extending between said cathodes and control grids and plate circuits connected between said cathodes and plate electrodes, connected in cascade and including a first stage, operating at a given frequency, a last stage and a plurality of intermediate stages, said last stage and said intermediate stages each being adapted to be locked to operate at a frequency which is a sub-multiple of said first stage, and capacitive circuits coupling said stages to each other, the capacitances in all of said coupling circuits being small as compared to the capacities of the grid circuits of the stages being locked and those in the circuits leading from the first stage and to the last stage being equal and those in the intermediate coupling circuits being likewise equal but higher than those in said first and last coupling circuits, said twin triode multivibrator stages

each having symmetrical high resistive plate circuits, unsymmetrical grid circuits and a dropping output resistance selectively connectible with the grid circuit of lowest resistance, and symmetrically disposed capacitances respectively connecting the plate circuit of one twin triode in series with the grid circuits of the other triode in each of said stages.

6. In a frequency generating system, a plurality of generators of complex waves of alternating voltages which are rich in harmonics, said generators comprising multivibrator stages connected in cascade and adapted to be locked for operation in a given sub-multiple frequency relation and each consisting of a duo-triode vacuum tube having sets of cathode, control grid and plate electrodes and providing a first triode and a second triode; grid and plate circuits for said electrodes extending respectively between said control grid and cathode and between said cathode and plate electrode, an output means for said system, a potential divider for each stage and comprising series resistances in the grid circuit of the first triode thereof and a dropping resistance, one terminal of which is connected to said grid circuit at the point between said series resistances, means for selectively connecting the other terminal of said dropping resistance to the associated cathode of said set of electrodes or to said output means, and a condenser coupling the grid of the second triode of any stage to the grid of the first triode of the next succeeding stage in said cascade the capacitance of which is less than the capacity of the grid circuit of the stage being locked, whereby a sharp control pulse wave consisting of only the higher harmonic components is injected into the grid of said second triode and to limit the output from the first triode to only a small fraction of the voltage generated thereby and thereby prevent distortion of the output complex wave.

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