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O. R. MILLER

2,477,076

FREQUENCY CONTROL SYSTEM

Filed Oct. 12, 1945

FIG. 1

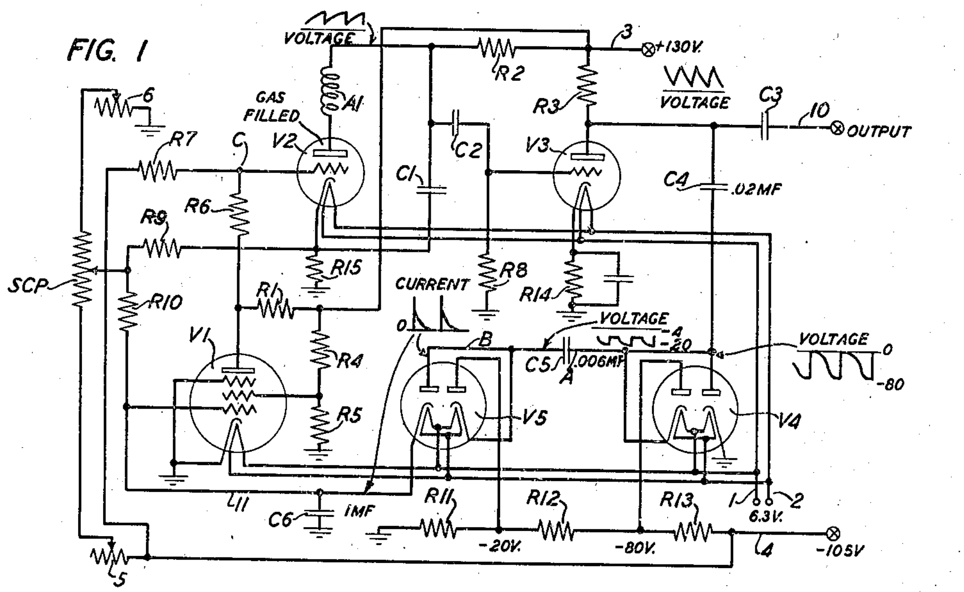
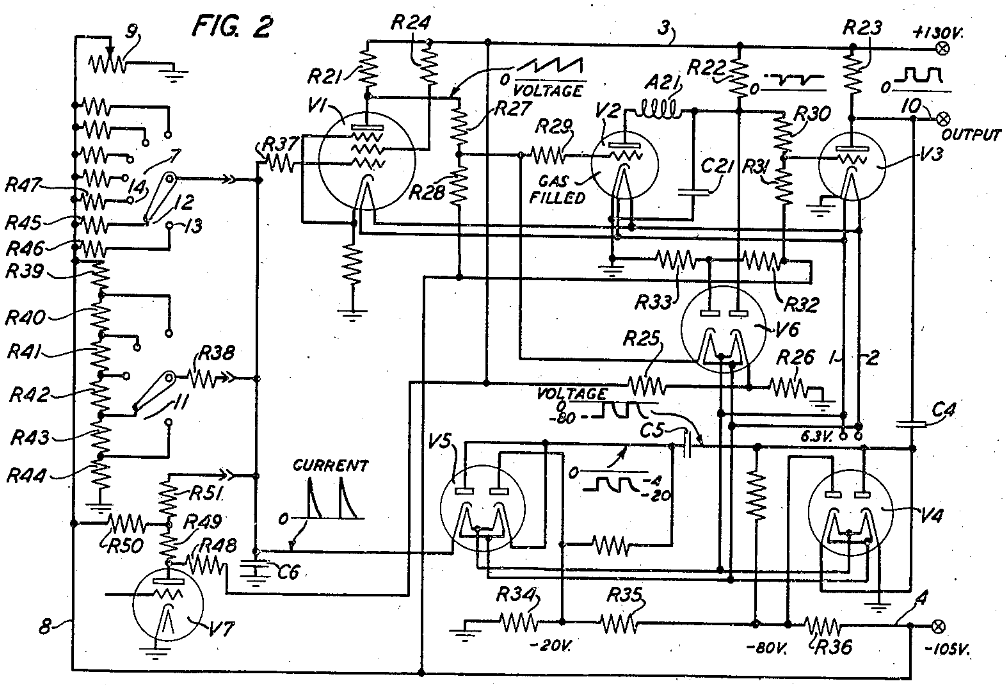


FIG. 2



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FREQUENCY CONTROL SYSTEM

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Application October 12, 1945, Serial No. 622,071

11 Claims. (Cl. 250—36)

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This invention relates to a frequency control system and more particularly to a system in which an output signal of variable frequency is produced, the frequency being varied in accordance with a first direct current signal and in which a second direct current is produced from the output signal which varies in accordance with the frequency and is effective together with the first direct current signal to stabilize the effect of the first signal in changing the frequency.

It is an object of the invention to enable the variation of the frequency of the output of a relaxation oscillator by a variable direct current control signal.

It is a further object of the invention to enable the stabilization of the frequency of the output of the relaxation oscillator in a simple and reliable manner.

To attain these objects a relaxation oscillator circuit is provided which comprises a preliminary direct current amplifier, an oscillator tube of the gas-filled type and a vacuum tube amplifier. In accordance with one embodiment of the invention, the frequency of the output of the oscillator tube is controlled by varying the cathode potential of the oscillator tube by the application of a variable direct current potential thereto and the frequency of the output of the oscillator tube is stabilized by a feedback circuit comprising a condenser and two diode limiter tubes. The condenser and the diode tubes function to convert the output impulses from the oscillator tube, and as amplified by the amplifier tube, into surges of current for charging a storage condenser whereby such latter condenser will be charged to a degree commensurate with the frequency of the output from the oscillator tube. The charge in such storage condenser is balanced against a charging current commensurate with the variable direct current potential which controls the oscillator tube whereby any change in the summation of the charges in the storage condenser is effective through the preliminary differential amplifier tube to vary the grid potential of the oscillator tube and to thereby change the period of oscillation until the change in the charge condition is removed.

In accordance with a further embodiment of the invention, the plate and grid potentials of the oscillator tube at which the tube will fire are held to fixed values and the surges of current delivered to the storage condenser by the feedback circuit in accordance with the frequency of the output of the oscillator tube are instrumental in conjunction with the variable control current in creating a potential having a saw-tooth wave form at the grid of the oscillator tube, the periodicity of which varies with the potential of the control signal. To insure that the voltage applied to the control condenser asosciated with the oscillator tube shall not exceed a determined value and to prevent the otherwise large negative swing of the grid voltage from causing a premature and harmful stoppage of the condenser discharge through the oscillator tube, an additional diode limiter tube is provided.

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The variation of the control signal voltage may be controlled by a variable resistance device such as a multiterminal switch to the stationary terminals of which different values of potential are applied from a source of direct current through parallelly connected resistances of different values; by a variable voltage divider such as a multiterminal switch, the terminals of which are connected to a plurality of taps of a resistance connected in series with a direct current source; by a potentiometer or by an electronic control.

While the invention is of quite wide application, it is particularly useful in circuits of the type disclosed in the application of R. H. Gumley, Serial No. 622,065, filed October 12, 1945 concurrently herewith in which a relaxation oscillator of this type is employed to simulate in an operational flight trainer the noise incident to the operation of an airplane engine whereby the periodicity of the noise impulses is caused to increase commensurately with the increase in the simulated engine speed.

For a clearer understanding of the invention and its mode of operation, reference may be had to the following detailed description when read in connection with the accompanying drawing in which:

Fig. 1 shows one embodiment of the invention; and

Fig. 2 shows a further embodiment of the invention.

In each figure of the drawing, tube V2 is a relaxation oscillator of the gas-filled or thyratron type, V1 is a pentode vacuum tube functioning as a direct current amplifier, tube V3 is an amplifier and tubes V4, V5 and V6 are diode vacuum tubes serving as rectifiers and limiters. The filaments of all of these tubes are heated from a source of 6.3 volts alternating current over branches of the bus-bars 1 and 2.

In Fig. 1 plate potential is applied from the +130-volt bus-bar 3 to the plate of tube V1 through the plate resistor R1, to the plate of tube V2 through the plate resistor R2 and choke coil A1, and to the plate of tube V3 through the plate resistor R3. Potential is also applied from bus-bar 3 through the potential divider comprising resistors R4 and R5 from which screen grid potential is derived for the amplifier tube V1. Grid bias is supplied to the grid of tube V2 from the potential divider including resistors R1, R6 and R7 connected between the +130-volt bus-bar 3 and the −105-volt bus-bar 4 of the direct current supply source and biasing potential is supplied to the grid of amplifier tube V3 through the grid bias resistor R8. Negative potential of −80 volts is supplied to the plate of the left unit of diode tube V4 and negative potential of −20 volts is supplied to the plate of the right unit of diode tube V5 from taps on the voltage divider comprising resistors R11, R12 and R13 connected in series between ground and the −105-volt bus-bar 4 of the direct current supply source. A variable negative control potential for controlling the frequency of the output of the oscillator tube V2 is applied through resistor R9 to the cathode of tube V2 and through resistor R10 to the condenser C6 from the slider of the signal control potentiometer SCP, the winding of which potentiometer is energized over a circuit extending from the −105-volt terminal of the source of direct current, through the calibration rheostat 5, through the winding of such potentiometer and through the calibration rheostat 6 to ground. The calibration rheostats may be adjusted to determine the upper and lower limits of the potential drop across the winding of potentiometer SCP and thereby the upper and lower limits of the negative potential applicable from the slider of such potentiometer to the cathode of tube V2 and to the condenser C6. Negative grid bias is supplied to the grid of amplifier tube V3 through resistor R14.

In Fig. 2, plate potential is applied from the +130-volt bus-bar 3 to the plate of tube V1 through the plate resistor R21, to the plate of tube V2 through the plate resistor R22 and choke coil A21 and to the plate of tube V3 through the plate resistor R23, and potential is also applied through resistor R24 to the screen grid of tube V1. From a tap in the voltage divider including resistors R25 and R26 connected between the bus-bar 3 and the negative grounded terminal of the +130-volt plate supply source potential is applied to the cathode of the right unit of diode tube V6. Grid bias is supplied to the grid of tube V2 from the voltage divider comprising resistors R21, R27 and R28 connected between the +130-volt bus-bar 3 and the −105-volt bus-bar 4, through the grid bias resistor R29, grid bias is supplied to the grid of tube V3 from the voltage divider comprising resistors R22, R30 and R31 bridged between the +130-volt bus-bar 3 and the −105-volt bus-bar 4 and negative potential is applied to the plate of the left unit of tube V6 from the voltage divider comprising resistors R32 and R33 connected between the −105-volt bus-bar 4 and ground. Negative potential of −80 volts is supplied to the plate of the left unit of diode tube V4 and negative potential of −20 volts is supplied to the plate of the right unit of diode tube V5 from taps in the voltage divider comprising resistors R34, R35 and R36 connected in series between ground and the −105-volt bus-bar 4. A variable negative control potential for controlling the frequency of the output of the oscillator tube V2 may be applied through resistor R37 to the control grid of the amplifier tube V1 from the movable arm of the switch 7 which may be set upon any one of the terminals of the switch, which terminals are connected through resistors of different resistance value to conductor 8 which in turn is connected between the −105-volt bus-bar 4 and ground through the calibration rheostat 9. The movement of the arm of switch 7 will vary the potential applied to the control grid of tube V1.

Alternatively, control potential may be applied to the control grid of tube V1 through resistors R37 and R38 from the movable arm of the switch 11 which may be set upon any one of the fixed terminals of the switch to include one or more resistors of the voltage divider comprising resistors R39 to R44, inclusive. The control voltage may also be controlled by the electronic device such as the tube V7.

Considering first the manner in which the circuit of Fig. 1 functions, it will be assumed that upon the connection of the +130-volt source to the bus-bar 3, condenser C1 associated with the oscillator tube V2 becomes charged over a circuit from bus-bar 3, through resistor R2, condenser C1 and through resistor R15 to ground and as it becomes charged, the potential applied through choke coil A1 to the plate of tube V2 rises. With the −105-volt source connected to bus-bar 4, current flows through the potential divider comprising rheostat 5, potentiometer winding SCP and rheostat 6 to ground and with the slider of potentiometer SCP assumed to be at the upper terminal of its winding, a minimum value of negative control signal potential is derived at the slider and applied through resistor R9 to the cathode of the oscillator tube V2. At this time potential derived at the junction point C of the potential divider extending from bus-bar 3 through resistors R1, R6 and R7 to bus-bar 4 is applied to the control grid of tube V2. When now the plate of tube V2 has become sufficiently positive, tube V2 conducts and establishes a low resistance discharge path for condenser C1, through choke coil A1 and over the cathode-plate path through the tube. Condenser C1 now discharges until the potential across the tube V2 is insufficient to maintain the cathode to plate current and the tube stops conducting and condenser C1 again starts charging.

While the tube V2 is conducting the grid potential of the amplifier tube V3 becomes more negative so that the resistance of tube V3 increases with the result that the charging path from bus-bar 3 through resistor R3 and through condenser C4 to the plate of the right unit of the diode limiter tube V4 becomes effective. With the cathode of this right unit connected to ground the unit becomes conducting and condenser C4 now charges therethrough until the potential on the plate of tube V4 becomes zero at which time condenser C4 will cease charging.

When the tube V2 ceases to conduct and condenser C1 starts to recharge the potential through the coupling condenser C2 rises and the grid of amplifier tube V3 becomes more positive with the result that the resistance of tube V3 decreases. A discharge path for condenser C4 is now effective from ground through resistor R14, over the cathode-plate path through the tube V3, through condenser C4, over the cathode-plate path through the left unit of tube V4 to the −80-volt tap on the potential divider comprising resistors R11, R12 and R13. Condenser C4 will continue to discharge until the potential applied over the discharge path through the cathode of the left unit of tube V4 reaches a value of −80 volts, or the plate potential of such unit of tube V4. The two units of tube V4 thus function to limit the potential appearing at junction point A from rising higher than zero or falling lower than −80 volts.

Condenser C4 will now continue to discharge over a path from point A through condenser C5 and over the cathode-plate path through the right unit of tube V5 to the −20-volt tap of the voltage divider from which plate potential is supplied to the plate of the right unit of tube V5. Tube V5 will continue to conduct until, through the charging of condenser C5 from the condenser C4, the potential on the right cathode of tube V5 rises from −80 volts to −20 volts at which time condenser C5 will cease to charge and point B will attain a potential of −20 volts. The right unit of tube V5 thus functions as a limiter to hold the potential of point B from going below −20 volts.

When tube V2 again conducts the grid of amplifier tube V3 becomes more negative and the resistance of tube V3 increases whereupon condenser C4 starts to recharge as previously described in a path through the right unit of diode tube V4 and the potential at point A now rises to zero. With point B connected to the plate of the left unit of tube V5 and the cathode of such unit connected to the ungrounded terminal of condenser C6 which will at this time be at about −4 volts, the potential on the plate of the left unit of tube V5 will rise until it is positive with respect to the cathode and the left unit of tube V5 will now conduct and establish a low resistance discharge path from ground through the right unit of tube V4, through condenser C4, through the left unit of tube V5 and to condenser C6 and the charge on condenser C5 will be transferred to condenser C6.

As the condenser C5 discharges the potential on the plate of the left unit of tube V5 decreases. When this potential reaches a value of −4 volts, at which time the potential on both the plate and cathode of the left unit of tube V5 will be −4 volts, the left unit of tube V5 will cease to conduct. When the potential at point A decreases from zero to −80 volts the potential at point B decreases and as the plate of the left unit of tube V5 now becomes negative to the cathode no current can return from condenser C6 to condenser C5. When the potential at point B reaches −20 volts, the right unit of tube V5 will now conduct, keeping point B at −20 volts and charging the condenser C5 as the point A decreases to −80 volts. The right unit of tube V5 thus serves to charge condenser C5 when the potential at point B decreases and the left unit of tube V5 discharges the condenser C5 when the potential at point B rises.

As oscillator tube V2 continues to operate under the control of the cathode control potential and the successive charging and discharging of control condenser C1, the cycle of operations above described is repeated. In response to the repeated charging and discharging of condenser C5 the charge thus applied to condenser C6 will increase and since the impulses of charge delivered to it by condenser C5 are all of the same magnitude the charge accumulated by condenser C6 will be a measure of the frequency at which tube V2 is firing. Condenser C6, however, is also charged in the opposite sense in accordance with the setting of the slider of potentiometer SCP and this to a degree commensurate with the control signal, by the potential derived at the slider of potentiometer SCP as applied to the condenser through resistor R10. If now the potential applied to condenser C6 as a measure of the frequency of the output of oscillator tube V2 is equal to the signal potential, there will be no change in potential at the control grid of the differential amplifier tube V1 and consequently no change in the potential applied to the control grid of the oscillator tube V2. The oscillator tube will therefore continue to oscillate at the frequency determined by the potential applied to its cathode.

Should the frequency of the output of tube V2 increase beyond that which should be commensurate for the input signal then the charge in condenser C6 as a measure of such signal output will increase and become greater than the potential applied to such condenser from the signal input and will result in the grid of tube V1 becoming more positive and the potential applied from point C to the control grid of oscillator tube V2 becoming more negative. As a consequence it will become necessary for the condenser C1 to charge for a longer interval before the potential applied across the tube will fire the tube. The interval between impulses generated by tube V2 will then be lengthened and the periodicity of the output will be decreased until a balanced condition at the grid of tube V1 is again attained. Conversely, should the frequency of the output of tube V2 decrease below that which should be commensurate for the input signal then the charge in condenser C6 as a measure of such signal output will decrease and become less than the potential applied to such condenser from the signal input and will result in the grid of tube V1 becoming more negative and the potential applied from point C to the control grid of tube V2 becoming more positive. As a consequence it will become necessary for condenser C1 to charge for a shorter interval before the potential across the tube will fire the tube. The interval between the impulses generated by tube V2 will thus be shortened and the frequency of the output of tube V2 will be increased until a balanced condition at the grid of tube V1 is again attained.

If the slider of potentiometer SCP should be moved further toward the lower terminal of its winding thereby increasing the negative potential applied from such slider through resistor R9 to the cathode of tube V2 and through resistor R10 to condenser C6, the cathode to plate current in tube V1 will decrease and the grid of tube V2 will become more positive whereby condenser C1 will be required to charge to a lower potential before the potential across the tube becomes sufficiently high to cause the tube to fire. The result will be that the periodicity of the output tube V2 will increase.

The modified circuit disclosed in Fig. 2 is similar to that of Fig. 1 and functions in much the same manner. To start the cycle of operations +130 and −105-volt sources are connected to the bus-bars 3 and 4, respectively and the source of heater current is connected to the bus-bars 1 and 2 for heating the filaments of all of the tubes. With +130-volt potential connected to bus-bar 3 potential is applied through resistor R22 to the plate of the right unit of tube V6 and with the cathode of such tube supplied with potential from the potential divider comprising resistors R25 and R26 connected between bus-bar 3 and ground, tube V6 functions to establish a shunt of the charging circuit of condenser C21 so that the charging potential applied from bus-bar 3 through resistor to condenser C21 will not be higher than a desired maximum value. Condenser C21 will thus become charged to a maximum value at a rate determined by the time constant of the circuit comprising the condenser and resistor R22 and as it becomes charged the positive potential applied from bus-bar 3 through resistor R22 and choke coil R21 will rise.

It will be assumed that the arm of switch 7 is connected through condenser C6 to ground and through resistor R37 to the control grid of amplifier tube V1 so that condenser C6 becomes charged negatively or discharged at a rate determined by the value of resistor R45 and the capacitance of the condenser. As condenser C6 discharges, the potential on the grid of tube V1 becomes more negative with the result that the potential applied from the potential divider comprising resistors R21, R27 and R28 connected between the bus-bars 3 and 4 become more positive until a potential is established across tube V2 to cause such tube to conduct. When tube V2 conducts condenser C21 then discharges over a circuit extending through such condenser, through the choke coil A21 and over the plate-cathode path through the tube. When the potential across the tube is insufficient to maintain the cathode to plate current the tube stops conducting and condenser C21 again starts to recharge.

The interrupted signal generated by the oscillator tube V2 is applied through the coupling resistor R30 to the control grid of the amplifier tube V3 and with positive plate potential connected to the plate of the latter tube, tube V3 functions to amplify the interrupted signal output of tube V2 and to apply the amplified output to the work circuit 10. A portion of the output of amplifier tube V3 is fed back in the form of positive impulses of current to condenser C6 in the manner fully described in connection with the discussion of the circuit of Fig. 1.

In the circuit of Fig. 2 the condenser C6 is made of such capacity that each small surge of current therethrough from the left unit of tube V5 will counteract against the discharging current applied from switch arm 7 so that the potential applied to the grid of amplifier tube V1 will suddenly become more positive resulting in suddenly causing the grid potential of tube V2 to become more negative. As a consequence the potentials applied to the grids of tubes V1 and V2 will have saw-toothed wave forms and tube V2 will become conducting at the peak of each grid potential wave.

The potential in the C6 condenser will move between two fixed voltages at any frequency of the output impulses of tube V2, with the right unit of limiter tube V6 functioning to cause condenser C21 to attain a fixed potential at the time of firing of tube V2. As the condenser C21 has a fixed potential at the instant tube V2 fires the voltage on the grid of tube V2 has a fixed value to cause the tube to fire and which, as above described, is determined by the lowest potential limit of condenser C6 at the instant such condenser receives a surge of current from the tube V5. At the instant tube V2 fires the square wave at the output of tube V3 causes a short surge from condenser C5 to condenser C6 as previously described. This surge has a fixed amplitude and duration at any frequency and causes the potential in the C6 condenser to rise a fixed amount. Hence the saw-toothed wave potentials at the grids of tubes V1 and V2 have the same voltage limitation for any frequency.

The discharge time of the condenser C6 from its upper to its lower limits is controlled by the direct control current applied at the arm of switch 7 and hence the frequency of the output of oscillator tube V2 is controlled by the potential applied at the arm of switch 7. If, for example, the arm is moved to terminal 13 over which terminal a large value of resistance is included through resistor R46 in the circuit over the arm of switch 7 to condenser C6, the time required to discharge condenser C6 to the same lower potential becomes longer and consequently the time required to raise the grid potential of tube V2 to the value at which tube V2 fires will become longer and tube V2 will fire at a slower rate. If, conversely, the arm of switch 7 is moved to terminal 14 over which terminal a smaller value of resistance is included through resistor R47 in the circuit over the arm of switch 7 to condenser C6, then the time required to discharge condenser C6 to the same lower potential becomes shorter and consequently the time required to raise the grid potential of tube V2 to the value at which tube V2 fires will become shorter and tube V2 will fire at a faster rate.

To hold the oscillator at zero frequency that is, to keep it from oscillating the voltage on condenser C6 must be held at some value above the breakdown value. The only current flow to or from the condenser under this condition is the grid current flow of the tube V1. An instant change of this control voltage and current condition to a value for some desired frequency output will cause the condenser C6 discharge curve to start from the holding voltage value and hence the time to the first output impulse can be controlled by the value of the holding potential and current.

If a peak or saw-toothed wave output is desired, a buffer tube may be controlled by the plate circuit of the V2 or V1 tube. The control circuit for this buffer tube should be designed to impose a fixed impedance load on the V2 or V1 tube if it is desired to maintain the above discussed frequency control.

To limit the negative potential on the grid of tube V2 to prevent the otherwise negative swing of the grid from causing a premature and harmful stoppage of the discharge of condenser C21 through the tube V2, the grid of tube V2 is connected through resistor R29 with the cathode of the left unit of tube V6, to the plate of which negative potential is supplied from the potential divider connected from the —105-volt bus-bar 4 to ground through resistors R32 and R33. When the potential on the grid of tube V2 and thus the potential on the left cathode of tube V6 becomes sufficiently negative with respect to the left plate of tube V6, cathode-plate current will flow in the left unit of tube V6 and a portion of the negative potential applied to the grid of tube V2 is thus enabled to leak off through the left unit of tube V6.

Control current for discharging condenser C6 may be applied from the arm of switch 11 through resistor R38, a switch 11 serving as a multitap potentiometer for deriving a potential from the resistors R39 to R44, inclusive, connected in series from conductor 8 to ground, or a variable control current may be derived from the potential divider including resistors R48, R49 and R50 connected between the bus-bars 3 and 4 and applied through resistor R51 to condenser C6 under the control of tube V7, the input circuit of which may be caused to respond to a variable potential change.

What is claimed is:

1. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, means for producing a first direct current control signal for varying the frequency of said generated output wave, a frequency detector for producing a second direct current signal from said output wave which varies in accordance with the variation in the frequency thereof, and an amplifier tube responsive to the summation of said first and said second direct current signals for applying a control signal to the input circuit of said oscillator tube to control the output frequency of said tube and to stabilize the effect of the first direct current control signal in varying the output frequency of said oscillator tube.

2. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, means for producing a first direct current control signal, means for applying said signal to the input circuit of said tube for varying the frequency of the generated output wave, a frequency detector for producing a second direct current signal from said output wave which varies in accordance with the variation in the frequency thereof, and a differential amplifier tube responsive to the summation of said first and said second direct current signals for applying a stabilizing signal to the input circuit of said oscillator tube to stabilize the effect of the first direct current control signal in varying the output frequency of said oscillator tube.

3. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, means for producing a first direct current control signal, means for applying said signal to the input circuit of said tube for varying the frequency of the generated output wave, a frequency detector for producing a second direct current signal from said output wave which varies in accordance with the variation in the frequency thereof, means for storing a derivative of said first direct current signal and said second direct current signal, and an amplifier tube responsive to said storage means for applying a stabilizing signal to the input circuit of said oscillator tube to stabilize the effect of the first direct current control signal in varying the output frequency of said oscillator tube.

4. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, means for producing a first direct current control signal, means for applying said signal to the input circuit of said tube for varying the frequency of the generated output wave, a frequency detector for producing a second direct current signal from said output wave opposite in polarity to said first direct current signal and which varies in accordance with the variation in the frequency of said output wave, means for storing a derivative of said first direct current signal and said second direct current signal, and an amplifier tube responsive to the unbalance between the signals stored in said storing means for applying a stabilizing signal to the input circuit of said oscillator tube to stabilize the effect of the first direct current signal in varying the output frequency of said oscillator tube.

5. In a frequency control system, means for generating an alternating current wave the frequency of which may be controlled, means comprising a condenser for producing a direct current from said alternating current wave which varies in accordance with the variation in the frequency of said alternating current wave, means for causing the charge and discharge of said condenser in response to alternate half waves of said alternating current wave, means for limiting the magnitude of each condenser charge, and means for applying the direct current discharge impulses from said condenser to said generating means to control the frequency of said alternating current wave.

6. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, a limiter tube for limiting the plate potential of said oscillator tube, whereby said plate attains the same potential upon each conducting cycle of said tube, a signal control means, and means controlled by said signal control means for generating and applying a potential having a saw-toothed wave form of variable periodicity to the input circuit of said tube, whereby said tube is caused to generate said current wave at the frequency determined by the periodicity of the wave form of said control potential.

7. In a frequency control system, a gas-filled tube, a condenser connected between the cathode and anode of said tube whereby said tube functions as a relaxation oscillator to generate an alternating current wave the frequency of which may be controlled, a limiter tube connected in parallel with the charging circuit of said condenser, whereby said condenser attains a fixed voltage level on each charging cycle, a signal control means, and means controlled by said signal control means for generating and applying a potential having a saw-toothed wave form of variable periodicity to the input circuit of said oscillator tube, whereby said tube is caused to generate said current wave at the frequency determined by the periodicity of the wave form of said control potential.

8. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, a signal control means, means controlled by said signal control means for generating and applying a potential having a saw-toothed wave form of variable periodicity to the control grid of said tube, whereby said tube is caused to generate said current wave at the frequency determined by the periodicity of the wave form of said control potential, and means for limiting the negative swing of the grid potential to prevent a premature stoppage of the conduction of said tube.

9. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, a condenser, a source of direct current, a signal control means for applying current from said source to said condenser for charging said condenser at variable rates, means for producing direct current impulses from said alternating current wave which vary in periodicity in accordance with the variation in the frequency of said alternating current wave and for applying said impulses to said condenser

whereby the potential across said condenser is varied in accordance with a saw-toothed wave form the periodicity of which is varied by said signal control means, and means controlled by said saw-toothed wave to control said oscillator tube to vary the frequency of the current wave generated thereby.

10. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, a condenser, a source of direct current, a signal control means for applying current from said source to said condenser for charging said condenser at variable rates, means for producing direct current impulses from said alternating current wave which vary in periodicity in accordance with the variation in the frequency of said alternating current wave and for applying said impulses to said condenser whereby the potential across said condenser is varied in accordance with a saw-toothed wave form the periodicity of which is varied by said signal controlled means, and an amplifier tube responsive to the potential across said condenser for applying a control potential having a saw-toothed wave form to the input circuit of said oscillator tube, whereby said oscillator tube is controlled to vary the frequency of the current wave generated thereby in accordance with the periodicity of said saw-toothed condenser potential.

11. In a frequency control system, means including a relaxation oscillator tube for generating an alternating current wave the frequency of which may be controlled, means for limiting the plate potential of said tube whereby said plate attains the same potential upon each conducting cycle of said tube, a condenser, a source of direct current, a signal control means for applying current from said source to said condenser for charging said condenser at variable rates, means for producing direct current impulses from said alternating current wave which vary in periodicity in accordance with the variation in the frequency of said alternating current wave and for applying said impulses to said condenser whereby the potential across said condenser is varied in accordance with a saw-toothed wave form the periodicity of which is varied by said signal controlled means, and an amplifier tube responsive to the potential across said condenser for applying a control potential having a saw-toothed wave form to the input circuit of said oscillator tube, whereby said oscillator tube is controlled to vary the frequency of the current wave generated thereby in accordance with the periodicity of said saw-toothed condenser potential.

OHMER R. MILLER.

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