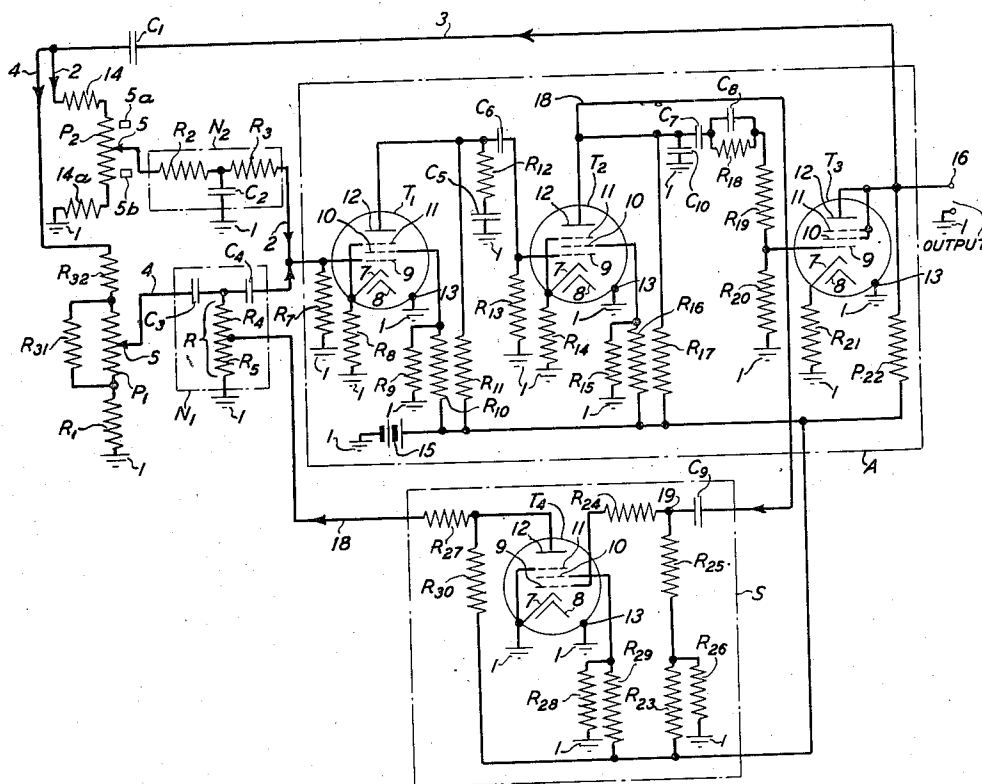


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A. A. LUNDSTROM
STABILIZED OSCILLATOR

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STABILIZED OSCILLATOR

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This invention relates to stable frequency oscillation generator circuits, and particularly to means for automatically stabilizing or controlling the amplitude level of oscillations.

One of the objects of this invention is to provide improvements in controlling the amplitude of oscillations in oscillation generators.

Another object of this invention is to improve the operation of variable frequency oscillators in respect to frequency and amplitude stability.

In accordance with one feature of this invention, the amplitude level of oscillations may be automatically stabilized over or throughout a range of variable operating frequencies by means of an auxiliary feedback system of the variable loss type. The variable loss principle may be applied to control not only the frequency of oscillations but also to control the level amplitude stabilization of the oscillations, a level sensitive amplitude control circuit replacing the conventional level sensitive resistance such as for example a thermistor, a carbon or tungsten lamp or a gas-filled tube. A simple, fast-acting and effective means of obtaining amplitude level stabilization may be provided with an auxiliary control circuit using a positively biased control grid in an amplifier type vacuum tube or pentode and special connections, in accordance with this invention.

In general, amplitude stabilized oscillators may comprise three basic units or parts, namely an amplifier which may be any suitable source of gain, a frequency sensitive network associated with the amplifier source of gain, and an amplitude control circuit for stabilizing the amplitude level of the oscillations. The frequency sensitive network may be, for example, a bridge type network having two parallel transmission paths in the main feedback path of the amplifier source of gain and which may as an example employ resistance-capacitance type elements in the frequency sensitive bridge networks. In addition, suitable means such as an adjustable resistance potentiometer associated with the networks may be utilized for varying the frequency of oscillations, as disclosed and claimed in a copending application for Variable frequency oscillators, Serial No. 577,622, filed February 13, 1945, by S. Darlington, now United States Patent No. 2,441,567, dated May 18, 1948.

The amplitude control circuit may be a variable loss type of amplitude stabilizer, the gain of which varies with the magnitude of the input oscillations applied thereto. The gain may be zero below a given amplitude level and above this level the gain to the fundamental may increase in ac-

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cordance with the excess of input over the given level. This action may be secured by means of a vacuum tube such as by pentode having a low screen grid potential, a high plate impedance and a positively biased control grid. Such a device is fast acting and capable of following very rapid changes in the amplitude of the oscillations applied thereto, and may be used with any type of oscillator that is provided with a parallel feedback path wherein the output of the positively biased pentode may be introduced in proper phase opposition relation with respect to signal oscillations which are to be controlled in amplitude.

As an illustrative example, the amplitude control circuit is herein shown as being particularly employed in connection with a specific type of bridge type oscillator having a frequency sensitive double-T network consisting of resistance and capacitance elements only, and in addition an adjustable resistance potentiometer which introduces a variable loss in the transmission for correspondingly varying the frequency of oscillation. The amplitude control circuit consists of a pentode having a positively biased control grid to which is also applied the oscillating signal taken from the oscillation output. If the oscillating signal potential applied to the control grid of the pentode exceeds in magnitude the positive bias applied to the same control grid of the pentode, plate current pulses of smaller amplitude will be caused to flow for each excursion of the oscillation signal amplitude in excess of the positive bias. The resulting plate current control pulses from the pentode are then applied through a direct current blocking condenser to the frequency sensitive network at a proper terminal thereof so that the control pulses oppose the oscillating signal potential in the network and thereby keep the amplitude of the oscillations within the linear amplitude range of the main amplifier source of gain.

As applied to a particular variable frequency loss controlled oscillator, the oscillator may comprise a suitable linear amplifier source of gain, a main feedback path having two parallel transmission paths each contributing to the total feedback, frequency sensitive networks in one or both of the two parallel transmission paths, means for introducing flat loss or gain into one or both of the two parallel transmission paths, and the auxiliary amplitude stabilizing control circuit. In the two parallel transmission paths, the frequency sensitive networks may be such that the corresponding contributions to the total feedback have the following properties—(a) the two con-

tributions to the feedback corresponding to the two parallel transmission paths differ in phase by an amount which is substantially 180 degrees independent of frequency; (b) the amplitudes of said two contributions vary differently with frequency, the usual difference being a change in the relative levels of the contributions at a rate which may be of the order of substantially 12 decibels per octave of frequency change, the above conditions applying to the relative phases and levels of the two contributions to the feedback and not to the actual phase and level of the total feedback; and (c) the two amplitudes are equal at a definite frequency which is substantially the frequency of oscillation. The means for introducing flat loss or gain into one or both of the two transmission paths referred to does so in such a way that the difference between the levels of the corresponding contributions to the feedback can be changed at will by amounts which are substantially independent of frequency if levels are measured on a logarithmic or decibel basis, and in such a way as to leave the two contributions substantially unchanged, the variation in flat loss controlling the variation in frequency of oscillation of the oscillator by varying the frequency at which the amplitudes of the two contributions to the feedback are equal. The stabilizing element referred to may be a level sensitive variable control circuit which may produce an effective change in one of the networks referred to and change the feedback in a subsidiary feedback path. The main source of gain referred to may be provided with the stabilizing control circuit in a way to meet conditions of high feedback amplifier stability.

The oscillator circuit illustrated in the accompanying drawing is a specific embodiment of a more general class of bridge type feedback oscillator circuits. The circuit illustrates the use of variable loss or variable voltage ratios means for variable control or modulation of the frequency, as distinguished from the use of variable adjustable bridge arms in the feedback β circuit bridge for control of the frequency. The circuit disclosed features the use of variable control of the frequency by variable loss devices and also stabilization by variable amplitude control devices. These are two independent features, the latter of which may be used with or without the other.

For a clearer understanding of the nature of this invention and the additional advantages, features and objects thereof, reference is made to the following description taken in connection with the accompanying drawing, in which like reference characters represent like or similar parts and in which the sole figure is a circuit diagram illustrating a variable frequency oscillation generator of the bridge stabilized type employing a frequency sensitive network with a variable loss control device in the form of a variable potentiometer for varying the frequency of oscillations, and also employing a positively biased grid pentode, in combination with the frequency sensitive network for automatically stabilizing or controlling the amplitude of oscillations.

The sole figure of the drawing is a circuit diagram of a variable frequency bridge type oscillation generator provided with variable resistance potentiometers P1 and P2 which are utilized to adjust and control the frequency of oscillation, and also provided with an amplitude level stabilizing circuit 13 which is utilized to stabilize the amplitude of the oscillations generated. As illustrated, the variable frequency oscillation gener-

ator has a frequency sensitive bridge network of the resistance-capacitance type which may be conveniently utilized for generating the relatively lower values of frequencies over or throughout a relatively wide range of low frequencies by adjustment of the variable resistance potentiometer P2.

As particularly illustrated in the drawing, the oscillator may comprise an amplifier or source of gain A consisting of a series of three high gain amplifying vacuum tubes T1, T2 and T3 provided with suitable interstage coupling means therebetween. A main feedback circuit 3 couples the output 16 of the third vacuum tube T3 with the input of the first vacuum tube T1 and comprises a coupling condenser C1, and a pair of parallel-connected transmission paths 4 and 2 which include networks N1 and N2, respectively, and also variable resistance potentiometers P1 and P2, respectively, both of which have a resistance component thereof connected in series circuit relation with the networks N1 and N2, respectively. The variable resistance potentiometer P1 is used only as a frequency trimmer, and its loss is thus held within narrow limits by the use of series resistances R1 and R2, and a shunting resistance R31. The main tuning resistance potentiometer P2 and the trimmer potentiometer P1 are connected with the main feedback circuit 3. The other ends of the potentiometers P1 and P2 are connected with the ground 1. The several ground connections 1, which are designated in the drawing by the conventional symbol for a ground connection, may be connected together in practice by means of any suitable wire connectors. The output oscillations may be taken from the output terminal 16 and the ground terminal 1 or from points connected therewith.

In practice, it is frequently desirable to use an amplifier A in which the phase between the input and output circuits is reversed. Such an amplifier A may be obtained by employing an odd number of amplifying tube stages, such as the three vacuum tube stages illustrated by the direct-coupled three-stage amplifier tubes T1, T2 and T3 in the drawing. The tandem-connected linear amplifier tubes T1, T2 and T3 comprising the linear amplifier A, and also the amplitude stabilizer tube T4, may be for example high gain vacuum tubes of the pentode type having an indirectly heated cathode 7, a cathode heater filament 8, an input or control grid 9, a screen grid 10, a suppressor grid 11 connected with the cathode 7, a plate or anode electrode 12, and a metal envelope or tube which may be connected to ground as illustrated at 13 in the drawing. The cathode heater filaments 8 of the tubes T1, T2, T3 and T4 may be connected in parallel and supplied with heating current in a known manner from any suitable voltage supply source (not shown).

The first tube T1 of the amplifier A may have its cathode electrode 7 and its control grid electrode 9 connected to ground 1 through resistances R8 and R7, respectively, and may have its screen grid electrode 10 connected to ground 1 through a resistance R9. Suitable potentials for the screen grid electrode 10 and for the plate electrode 12 of the tube T1 may be supplied through resistances R10 and R11, respectively, from the positive (+) terminal of a suitable battery or power supply source 15. The interstage coupling between the first and second vacuum tubes T1 and T2 may comprise a resistance R12 with a grounded series-connected condenser C5

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and a coupling condenser C6. The second vacuum tube T2 of the amplifier A may be provided with a grid resistance R13, a cathode resistance R14 and a screen grid resistance R15. Suitable potentials for the screen grid electrode 10 and for the plate electrode 12 of the second amplifier tube T2 may be supplied through resistances R16 and R17, respectively, from the positive terminal of the power supply source 15. The interstage coupling between the output of the second amplifier tube T2 and the input of the third amplifier tube T3 may include a condenser C7, a parallel-connected condenser C8 and resistance R18, a resistance R19, and a grounded condenser C10, as illustrated in the drawing. The third tube T3 of the linear amplifier A may be provided with a grid resistance R20 and a cathode resistance R21. Suitable potentials for the grids 10 and 11 and for the plate electrode 12 of the tube T3 may be supplied through resistance R22 from the positive terminal of the power supply source 15.

The network N2 as illustrated by the block diagram labeled N2 in the drawing, is constructed in the form of a T-network consisting of two series-connected resistances R2 and R3 and a single shunt condenser C2 which is connected at one end thereof to the ground 1. The network N1 as illustrated by the block diagram labeled N1 in Fig. 1 is constructed in the form of a T-network consisting of two series condensers C3 and C4 and a shunt resistance R which is composed of two series resistances R4 and R5, the latter being connected at one end thereof to the ground 1. The networks N1 and N2 taken together comprise a double-T or parallel-T network system and taken with the variable resistance potentiometers P1 and P2 form two parallel paths 4 and 2, respectively, in the main feedback circuit 3 of the linear amplifier A, the main feedback circuit 3 being connected between the output circuit 16 of the third amplifier tube T3 and the input of the first amplifier tube T1 of the amplifier A. The output circuits of the parallel-connected paths 4 and 2 and of the networks N1 and N2 are connected with the input of the first amplifier tube T1, and therebetween the resistance R7 is connected to ground 1 at one end thereof.

The bridge type feedback circuit frequency sensitive networks N1 and N2 may be practically any type of network system which provides a substantially constant 180-degree phase difference and different amplitude characteristics for varying frequency values. Since there are a large number of bridge circuits which provide such transmission characteristics, the network system N1 and N2 may consist of any of a large number of possible bridge circuit arrangements. The particular parallel-T networks N1 and N2 when composed of resistances and capacitances only as illustrated in Fig. 1, are particularly useful at the audio and lower frequencies. For the higher frequencies, inductances instead of resistances may be used in the networks N1 and N2.

In the circuit shown in the drawing, the frequency of oscillation depends intimately upon the resistances that are used in the networks N1 and N2 and hence they are constructed as precision units where precision is desired. At low frequencies, such as, for example, frequencies below 100 cycles per second, the resistance units of the networks N1 and N2 may be made large in order to avoid the use of unduly large precision capacitance devices. Since continuously vari-

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able precision resistance units are difficult to realize in practice in large sizes, the large precision resistances of the networks N1 and N2 may be fixed or non-variable resistances, the frequency of oscillation being adjusted or varied by one of the variable potentiometers P1 or P2 which may be made to be of relatively low resistance values and of relatively small size. In the circuit shown in the drawing, the variable resistance potentiometer P2 includes the end resistances 14 and 14a and represents a variable loss device which is used to furnish variable control over the frequency of the system by adjustment of the wiper 5 between the stops 5a and 5b. Since high precision in frequency imposes high precision on the resistances and other component parts of the networks N1 and N2, where a variable frequency is required, it is often difficult or impractical to obtain high precision in frequency control by means of adjustments in the large precision resistances and other component parts of the networks N1 and N2 themselves. For this reason, and for the same precision in frequency, the use of the potentiometer type of frequency control P2 is more easily realized in practice. The impedance of the potentiometer P2 being of relatively low value is more easily constructed in adjustable form. Moreover, the potentiometer voltage ratios of the adjustable potentiometer P2 can be normally held to close limits since the voltage ratio thereof depends upon the relative resistances rather than upon the absolute values of resistance. Accordingly, changes in the absolute values of resistance of the potentiometer P2, as caused by changes in temperature, for example, do not change the voltage ratio of the potentiometer P2 except to the extent that such changes in absolute resistance may not be uniform along the potentiometer P2.

While the potentiometer P2 presents a finite impedance to the load connected to the brush 5 thereof, its effect on the frequency stability of the system may be minimized by making the impedance of the resistance potentiometer P2 reasonably small relative to the impedance value of the resistance R2, to which the brush 5 of the potentiometer P2 is connected. The effect is to add resistance to the resistance R2 by the parallel combination of the segments of the potentiometer P2 above and below the brush 5 thereof. To the extent that the effective addition of such resistance to the resistance R2 is constant, it may be compensated for by a reduction in the resistance of R2 itself. The remaining variations in the equivalent resistance of R2 as a result of the effect of the resistance of the potentiometer P2 thereon may be taken care of in part by means of the amplitude stabilizer system such as, for example, by the amplitude control system comprising the auxiliary feedback circuit 18 including the stabilizer S with the tube T4, and in part by proper calibration of the voltage ratio provided by the resistance arms of the potentiometer P2. If desired, the taper of the resistance values of the potentiometer P2 may be used to obtain a linear variation of frequency with respect to the shaft position of the potentiometer P2. It will be understood, however, that the adverse effect of the variable resistance of the potentiometer P2 on the over-all stability of the oscillator system is not large when the impedance of the potentiometer P2 is reasonably small relative to the impedance value of resistance R2 of the network N2.

As illustrated in the drawing, the tuning potentiometer P2 has a resistance composed of a middle

portion connected with the adjustable wiper 5, and two end series resistance portions 14 and 14a. This construction, when used, insures that the potentiometer P2 cannot be set to a value corresponding to a frequency outside the range for which the circuit is designed. This is a desirable feature because the average $\mu\beta$ of the system ordinarily should be held within plus or minus 90 degrees of a negative real over the entire working range of frequencies. In providing the potentiometer P2 with suitable non-adjustable end resistance portions 14 and 14a, as illustrated schematically in the drawing, the possibility of setting the wiper 5 of the potentiometer P2 outside the working range of frequencies may be prevented.

As illustrated in the drawing, an auxiliary feedback circuit 18 may be provided between the plate output circuit 12 of the second amplifier tube T2 and the input circuit of the first amplifier tube T1 of the amplifier A in order to stabilize the amplitude level of oscillations generated. As shown in the drawing, the anode 12 of the second amplifier tube T2 of the linear amplifier A is connected through a blocking condenser C9 and a resistance R24 with the input control grid 9 of the pentode T4, and the output or plate electrode 12 of the tube T4 is connected through resistance R27, resistance R4, and condenser C4 with the input grid electrode 9 of the first amplifier tube T1 of the amplifier A. The input or control grid electrode 9 of the tube T4 is connected through resistances R23, R24 and R25 with the positive (+) terminal of the supply source 15. A resistance R26 is connected between ground 1 and a point intermediate the resistances R23 and R25. The middle or screen grid electrode 10 of the tube T4 is connected through a resistance R28 to ground 1, and through a resistance R29 to the positive terminal of the voltage supply source 15. Potential for the plate electrode 12 of the tube T4 is supplied through a resistance R30 which is connected with the positive terminal of the power supply source 15.

In the vacuum tube stabilizer system S of the drawing, positive bias voltage from the supply source 15 and signal voltage oscillations from the output of the second amplifier tube T2 of the amplifier A are combined at the junction 19, and are then fed to the control grid 9 of the tube T4 through a large resistance R24. The voltage at the junction 19 is a resultant of the oscillating signal voltage applied thereto and the positive bias voltage applied thereto from the supply source 15, the latter being supplied through resistances R25 and R23. Whenever the instantaneous value of the voltage at the junction 19 is positive, the control grid electrode 9 of the tube T4 draws current and produces a substantial voltage drop across the input resistance R24. Because the control grid current and also the voltage drop across the resistance R24 increases very rapidly with increasing voltage at the control grid 9 of the tube T4, the grid voltage at the control grid 9 of tube T4 changes very little during wide fluctuations of the voltage at the junction 19. As a result, the oscillating signal from the amplifier A applied to the tube T4 over the control circuit 18 is effectively blocked so long as the combination signal voltage and positive bias voltage at the junction 19 is positive over the entire cycle, which is so as long as the amplitude of the oscillation signal voltage applied to the junction 19 is less than the positive bias voltage at the junction point 19. The positive bias voltage

at the junction point 19 is the voltage from the battery 15 fractionated by the resistances R23 and R26 according to the factor

$$\frac{R26}{R23 + R26}$$

When the amplitude of the oscillation signal voltage at the junction 19 begins to exceed this value of the positive bias voltage, the voltage of the control grid 9 of the stabilizer tube T4 swings negative over a portion of each cycle. While such grid voltage is negative, the control grid 9 of the tube T4 draws no appreciable current and there is no appreciable corresponding drop across the control grid resistance R24. Hence, only portions of each cycle of the combination signal and bias voltages at the junction 19 are transmitted and amplified by the tube T4. The output of the tube T4 is fed into the network N1 of the oscillator through the resistance R4 and opposes the oscillating signal voltage therein, thus giving the desired level amplitude stabilization at a level at which the amplitude of the signal voltage at the junction 19 is slightly greater than the positive bias voltage at the junction 19.

The positive grid vacuum tube T4 accordingly functions to supply pulses of alternating voltage in opposition to the oscillation signal voltage in the network N1 thereby to provide level stabilization of the amplitude of oscillations. At the lower amplitude levels of the output voltage from the amplifier A, the vacuum tube T4, due to the steady positive bias applied to the control grid electrode 9 thereof from the supply source 15, effectively blocks the oscillations reaching it from the output of the second amplifier tube T2 over the circuit 18 and continues to do so until the amplitude of the oscillations reaches a critical level in amplitude. As the level increases further in amplitude, the tube T4 begins to transmit the oscillations to an extent that increases as the level of the amplitude of oscillations increases above the critical value mentioned. Accordingly, the effect on the circuit 18 of the tube T4 is to prevent transmission of oscillations at the low levels of amplitude and to transmit oscillations with the increasingly higher values of amplitude applied thereto.

The tube T4 is fed from the output of the second amplifier tube T2 or from the next to the last tube of the gain circuit A, rather than from the output 16 of the last amplifier tube T3 of the gain circuit A, in order to balance against the reversal through the stabilizer tube T4, the similar reversal in direction of signal that occurs in passing through the last tube T3 of the gain circuit A. A vacuum tube, such as the tubes T3 and T4, reverses the direction of the signal which it transmits. Hence the reversal through the stabilizer tube T4 is balanced by the similar reversal through the last tube T3 of the gain circuit A. The tube T4 fixes the amplitude level of oscillations at a value which is substantially independent of the frequency of oscillations, and accordingly a substantially constant oscillator output voltage level is obtained from the output 16 of the last amplifier tube T3 of the gain circuit A provided the tube T3 has a substantially constant gain over the working range of variable operating frequencies. The output of T3 is reversed in phase through the parallel networks N1 and N2 so that it appears as a positive feedback to the grid 9 of the tube T1. However, the output 18 of the tube T4 is applied to the network N1 at such a point that no further reversal in phase

is required. Thus the output of T4 tends to cancel and reduce the output of T3 at the grid 9 of the vacuum tube T1.

The amplitude stabilizer system 18 described in connection with the positive grid tube T4 has a number of advantages. It is fast acting and capable of following rapid changes of frequency due to changes in the setting of the frequency controlling tuning potentiometer P2 even though these changes of frequency setting of the potentiometer P2 call for substantial changes through the tube T4. It is a sensitive system giving a sharp rise in transmission at a definite amplitude level, and the amplifier tube T4 may be of the same type as the amplifier tubes T1, T2 and T3 of the μ circuit A of the oscillator. While considerable harmonics may be generated relative to the fundamental component transmitted by the tube T4, the amplitude of the harmonics and also of the fundamental itself that enters the β circuit over the circuit 18 is relatively small as compared with the amplitude of the oscillator signal voltage that is fed back over the main feedback circuit 3 from the output 16 of the last amplifier tube T3. Since the oscillator is essentially a negative feedback amplifier at frequencies other than the frequency of oscillation, the harmonics generated by the stabilizer tube T4 are reduced by the negative feedback.

In the amplitude level stabilizer system 18 illustrated in the drawing, a non-linear feedback voltage is produced which varies with the amplitude of the output voltage of the amplifier A and which operates to increase the damping of oscillations generated with increasing amplitude of output voltage. The feedback in the auxiliary feedback circuit 18 is in the opposite phase as that of the main feedback circuit 3 and increases with the level of the output voltage which gives satisfactory amplitude stability at low and high frequency cut-offs, is comparatively simple and operates well even at low levels of voltage applied thereto. This results from the feedback voltage from the output circuit of the oscillator being fed back through the vacuum tube T4 which has a substantial plus (+) bias on the control grid electrode 9 thereof. Where the positive or plus (+) bias and the oscillation signal are fed to the control grid 9 of the tube T4 through the high resistances R23, R24 and R25, the low impedance of the control grid 9 at plus (+) voltages operates to prevent any substantial signal voltage being fed back until the magnitude of the signal voltage becomes large enough to swing the control grid 9 negative, above which critical level there will be a sudden increase in transmission level through the vacuum tube T4. Thus the effective stabilizing voltage from the output of the tube T4 is very small in magnitude until the critical level referred to is reached, and thereafter it rises very rapidly with further increasing levels of oscillating signal voltage applied to the tube T4. A substantial value of positive (+) voltage bias may be applied from the supply source 15 to the high voltage side of the grid resistances R23, R24 and R25, without getting excessive positive (+) voltages on the control grid 9 itself of the tube T4 as a result of the I. R. voltage drop that occurs in such grid resistances when the control grid 9 of the tube T4 draws current.

It will be noted that since the stabilizing tube T4 gives a phase reversal, it is fed from the main amplifier A from a different interstage point, and preferably from the first interstage back of the final output tube T3, as illustrated in the drawing.

It will be noted that variations in the gain μ of the high gain linear amplifier A are absorbed by the non-linear stabilizer circuit 18 comprising the positive grid tube T4 without substantially any shifting of the frequency of oscillation provided the phase shift of the bridge network system N1 and N2 is relatively small. Provided that the phase shift of the bridge networks N1 and N2 referred to can be kept small enough, a rather small value of gain μ may be used if the precision required is not too high.

As an illustrative example, a particular oscillator constructed in accordance with the circuit of the drawing and having a variable frequency ranging from 30 to 90 cycles per second was provided with component resistances and condensers having substantially the following values. In the particular example mentioned, the values for the component resistances expressed in ohms were about: R1=65,000, R2=200,000, R3=206,000, R4=85,000, R5=12,000, R7=1,000,000, R8=2,000, R9=15,000, R10=100,000, R11=250,000, R12=25,000, R13=1,000,000, R14=2,000, R15=15,000, R16=100,000, R17=250,000, R18=10,000,000, R19=500,000, R20=500,000, R21=800, R22=10,000, R23=200,000, R24=1,000,000, R25=1,000,000, R26=30,000, R27=1,000,000, R28=15,000, R29=100,000, R30=1,000,000, R31=500, R32=720, P1=2,000, and P2=10,000 ohms total, the values of the end resistances 14 and 14a being 750 ohms each and the value of the middle resistance covered by the wiper 5 being 8500 ohms. In the particular example mentioned, the capacitance values for the component condensers expressed in microfarads were about: C1=1.0, C2=.016, C3=.008, C4=.008, C5=.005, C6=2.0, C7=1.0, C8=.012, C9=.1, C10=.005; and the tubes T1, T2, T3, and T4 were standard 12SJ7 pentodes having their cathode filaments energized from a cathode heating source of about 12.6 volts and provided with a battery or power supply source 15 of about +250 volts direct current potential.

It will be noted that the amplitude stabilized oscillator as illustrated consists mainly of the main linear amplifier source of gain A, the frequency sensitive network system including the networks N1 and N2, and the amplitude control circuit 18 which is combined with the network N1 of the double-T networks N1 and N2. As shown in the drawing, the networks N1 and N2 are of the resistance-capacitance type, and are controlled by the adjustable resistance potentiometer P2 for obtaining frequency variations, as disclosed and claimed in the S. Darlington application hereinbefore referred to.

The amplitude control circuit 18 includes the positively biased grid form of pentode T4 having a low potential rather than the usual high potential applied to its screen grid electrode 10 and having a high impedance provided for its plate electrode 12. To the positively biased control grid 9 of the pentode T4 is applied the alternating current signal oscillations from the amplifier A through the resistance R24 and the direct current blocking condenser C9. The positive bias potential applied to the control grid 9 of the pentode T4 is supplied from the direct current supply source 15 through the resistances R23, R25, and R24. If the signal oscillation exceeds in magnitude the positive bias voltage, plate current will be caused to flow in the pentode T4 at a small amplitude for each excursion of the signal oscillation amplitude that is in excess of the positive bias voltage. The resulting pulses of plate current are applied through the condenser C4 to the frequency

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sensitive network N1 at a point therein which is selected to oppose the main oscillating signal potential in that network, to thereby keep the amplitude of signal oscillations within the linear amplitude range of the main amplifier A. The series condensers C4 and C9 function as direct current blocking condensers. The pentode T4 is connected in the amplitude control circuit 18 between the blocking condensers C4 and C9.

The positive grid bias voltage E3, which is the potential across the resistance R26, is applied to the control grid 9 of the pentode T4 through the resistances R24 and R25. This positive bias potential E3 is derived from the battery voltage Eb of the source 15, and is properly fractionated with the resistances R23 and R26 so that the positive bias potential

$$E3 = Eb \left(\frac{R26}{R26 + R23} \right)$$

The resistance R25 is used to increase the impedance looking into this circuit from the output of the amplifier A and thus reduce the shunting loss at that point. The resistance R24 has a purpose similar to that of the resistance R25 since the grid-to-cathode path of the pentode T4 is normally conducting and has a low impedance when in that condition. Moreover, the resistance R24, as well as the resistance R25, by virtue of the high voltage drop therein due to the grid current flowing when the amplifier A output voltage e_0 plus the voltage E3 are positive, maintains a grid-to-cathode voltage Eg on the control grid 9 at almost a constant value, so that when the positive bias voltage E3 is greater than the voltage e_0 from the amplifier A there is little or no change in the plate current i_p of the pentode T4.

The resistances R28 and R29 represent a fixed potentiometer for reducing the bias voltage Es across the resistance R28 to a fraction of the voltage Eb of the source 15, so that the pentode T4 will have a quick-acting switch-like action. The plate resistance R30 is made large to provide sharp action. The value of the screen grid bias voltage Es of the pentode T4 is made small and the ratio between the plate current i_p and the control grid voltage Eg is made high. It is desirable to make the excess control voltage v as small as possible since the tightness of this stabilizing control voltage v is proportional or related to the gain of the amplifier A, to the loss in the frequency sensitive networks N1 and N2, and to the value of $1/v$. Since the output of the pentode T4 control voltage $e1$ is applied to the frequency sensitive network N1 in such a direction as to reduce the amplitude of the oscillating signal on the input of the linear amplifier A, it may be more precisely stated that the value of

$$\frac{di_p}{dv}$$

should be as large as possible. During operation, the control voltage $e1$ applied by the output of the amplitude control circuit 18 to the frequency sensitive network N1 will be a series of sharp interrupted pulses of unidirectional fluctuating voltages. The sharp pulses are sufficient to suppress uncontrolled oscillation of the main oscillator system. At the network N1, these pulses are small in magnitude as compared to the amplitude of the signal oscillation there, and are smoothed out by the network N1 and the negative feedback of the oscillator for frequencies, other than the oscillating frequencies in a manner to cause negligible distortion.

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The combination of the resistance R30 and the impedance seen looking into the network N1 should be as high as is necessary to make the load line intersect the characteristics of the pentode T4 so that the value of

$$\frac{di_p}{dv}$$

is maximum. The effect of reducing the potential on the screen grid 10 of the pentode T4 to a value well below the potential of the source 15 is to give a high resistance load line in a compressed section for the pentode T4 characteristics and to thereby obtain a maximum value of

$$\left(\frac{di_p}{de_g} \right) \text{ or } \frac{di_p}{dv}$$

The advantages of this type of amplitude control circuit as illustrated at 18 in the drawing include the following: The pentode T4 provides a sharp switch-like operation for applied oscillating signal potentials exceeding in magnitude the positive grid bias potential value, with no output when the amplitude of the applied signal potentials is below this positive bias value. This makes possible a tight or close amplitude stabilization as well as good frequency stabilization for the oscillator. The magnitude of the voltage of the oscillations to be controlled does not depend on the tube characteristics alone as in the case where a gas-filled tube is used. Hence the tube T4 can be easily adapted to suit oscillator design requirements in general, and the stability of the unit is as good as that of the power supply 15 and of the resistance potentiometers R23 and R26, which are or can be made to be very stable circuit elements. The points at which the tube T4 just operates and just not operates are equal, and without hysteresis effect. The amplitude control circuit 18 provides fast operation so that the frequency can be varied very rapidly over the desired range, and accordingly, it is a high speed circuit having a great advantage where the oscillator is continuously or rapidly varying in frequency. It provides an economical and simple circuit composed of standard parts which are suitable for use with the usual power supply units, such as the positive "B" supply 15 and the alternating current heater voltage supply 8. The amplitude control circuit 18 is not restricted to use with the particular bridge type oscillator illustrated in the drawing but may be used with any type of oscillator where the output from the circuit 18 is introduced into a parallel feedback path of the oscillator.

Although this invention has been described and illustrated in relation to specific arrangements, it is to be understood that it is capable of application in other organizations and is therefore not to be limited to the particular embodiments disclosed.

What is claimed is:

1. A variable frequency oscillation system comprising an amplifier or source of gain having a substantially linear amplifying characteristic, a main feedback path connected from the output of said amplifier to the input thereof, said main feedback path including a pair of parallel-connected transmission paths, each of said parallel transmission paths including a frequency sensitive network contributing to the total feedback in said main feedback path, said pair of parallel transmission paths having related phase and amplitude characteristics, the relative phase characteristics of said pair of parallel transmission

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paths differing by substantially 180 degrees and being substantially independent of a change in the value of said variable frequency, and the relative amplitude characteristics of said pair of parallel transmission paths varying differently with a change in the value of said variable frequency and being equal in amplitude at a definite frequency corresponding substantially to the value of said oscillation frequency, said parallel transmission paths including variable frequency control means for introducing variable attenuation or loss into at least one of said pair of parallel transmission paths for varying said relative amplitude characteristics thereof and for correspondingly varying the value of said variable oscillation frequency, and amplitude control means for providing substantially level sensitive amplitude stabilization of said oscillations within said substantially linear characteristic of said amplifier and over a range of values for said variable frequency, said amplitude control means comprising an auxiliary feedback circuit including a vacuum tube having a positively-biased control grid responsive to the amplitude of said oscillations from said amplifier for introducing voltage pulses of smaller amplitude than said amplitude of said oscillations into one of said parallel-connected networks at a point therein where said pulses are in opposition to the oscillations in said network.

2. An oscillation system in accordance with claim 1 wherein said parallel-connected networks include double T networks composed of resistance and capacitance elements, and wherein said amplitude control circuit vacuum tube has its output or plate circuit connected with a tap point in the central resistance of one of said T networks and in series relation with the capacitance element of said one of said T networks, and wherein said vacuum tube is a pentode having said positively biased control grid connected with and responsive to oscillations from said amplifier.

3. A generator of oscillations comprising an amplifier source of gain, a main feedback path connected from the output of said source of gain to the input thereof, frequency determining means comprising a plurality of parallel-connected frequency sensitive networks connected in said main feedback path and contributing to the total feedback in said main feedback path, frequency varying means comprising a variable resistor connected in said main feedback path in circuit with one of said parallel-connected networks for varying said frequency of said oscillations, and amplitude control means comprising an auxiliary feedback circuit having its input connected with said source of gain and having its output connected to one of said parallel-connected networks for stabilizing the amplitude of said oscillations at a substantially constant level over the range of said varying frequency, said auxiliary feedback circuit including a vacuum tube having a positively-biased control grid responsive to said amplitude of said oscillations received from said source of gain for introducing interrupted unidirectional voltage pulses of variable magnitude into said last-mentioned network at a selected point therein where said pulses oppose said oscillations in said network, and means including a resistor for applying to said control grid said positive bias potential at a predetermined substantially constant value, said value of said positive bias potential corresponding to a gain for said tube of substantially zero magnitude below a predetermined value of said am-

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plitude level of said oscillations applied thereto, and to a gain for said tube increasing in magnitude in accordance with the excess in amplitude of said oscillations over said predetermined value of said amplitude level of said oscillations applied thereto.

4. A source of oscillations comprising an amplifier having a substantially linear amplifying characteristic, a main feedback circuit means including frequency sensitive parallel-connected networks connected with said amplifier for controlling the frequency of said oscillations, and an amplitude control circuit for controlling the amplitude level of said oscillations within said substantially linear characteristic of said amplifier, said amplitude control circuit comprising means responsive to the amplitude of said oscillations to be controlled in amplitude for supplying fluctuating voltage pulses in opposition to said oscillations for stabilizing the amplitude level of said oscillations to be controlled, said amplitude control circuit comprising an auxiliary feedback circuit having its input connected with said source of oscillations and having its output connected in said frequency sensitive parallel-connected networks at a point therein where said pulses are in said opposition to said oscillations, said amplitude control circuit including a pair of direct current blocking condensers connected in series circuit relation in said control circuit and a vacuum tube connected in said control circuit between said pair of blocking condensers, said tube having a control grid connected with said source of oscillations to be controlled, and means including a resistance for applying a substantially constant positive bias potential of predetermined value to said control grid, the value of said positive bias potential corresponding to a gain for said tube of zero value below a predetermined value of the amplitude level of oscillations applied thereto and to a gain for said tube increasing in magnitude in accordance with the excess in amplitude of said oscillations over said predetermined value.

5. An oscillating system in accordance with claim 4 wherein said vacuum tube has said positively biased control grid, and has a screen grid electrode and a plate or anode electrode, and means including resistances of selected values for providing the output circuit of said plate electrode with a relatively high impedance and said plate electrode with a high positive plate bias potential, and means including a resistance for providing said screen grid electrode with a low potential relative to said plate bias potential.

ALEXIS A. LUNDSTROM.

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