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STABILIZED MULTIVIBRATOR OSCILLATOR

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FIG. 1

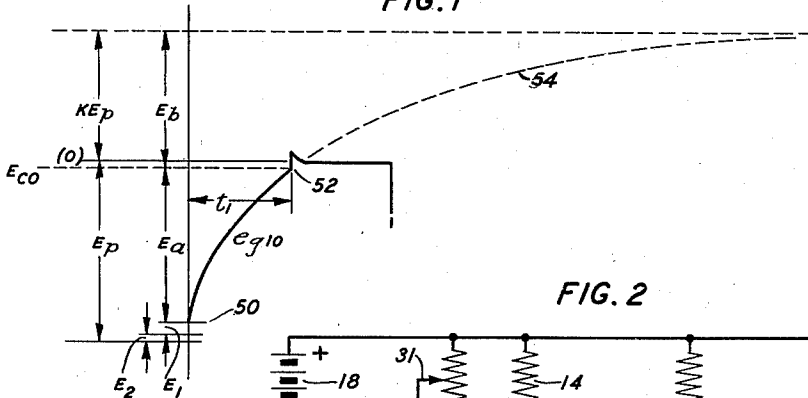


FIG. 2

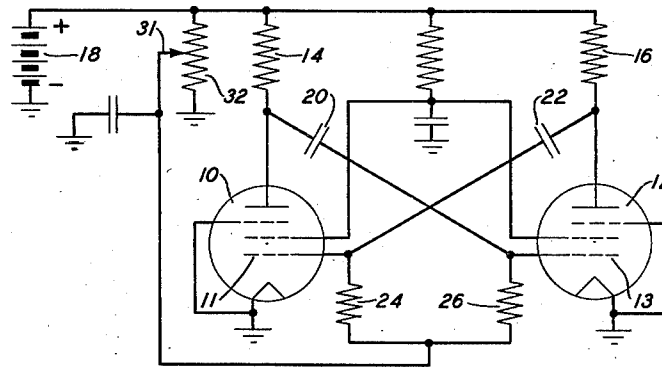
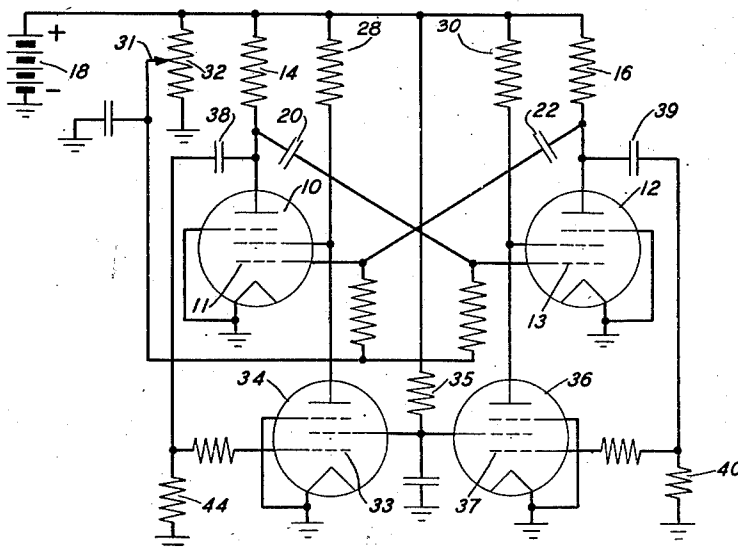


FIG. 3



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STABILIZED MULTIVIBRATOR OSCILLATOR

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9 Claims. (Cl. 250—36)

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This invention relates to oscillatory circuits and is especially concerned with improved methods and means for stabilizing relaxation type oscillatory circuits against unwanted frequency variations.

It is well known that the characteristics of many types of oscillators and particularly those of the relaxation type are subject to changes arising from variations in the circuit potentials, and also from changes in the relative positions of the electrodes of the included electron discharge devices. It is, of course, desirable that the oscillation frequency of these circuits be made independent of such circuit changes in so far as is possible. It is accordingly an object of this invention to make possible improved multivibrator type of oscillatory circuits in which frequency instability is reduced to a minimum.

It is also an object of this invention to make possible stabilized relaxation type oscillators, the operation and frequency output of which are substantially unaffected by variations in the anode potential supply.

It is a further object of this invention to make possible multivibrator type of oscillatory circuits in which the effect of variations in the cut-off and saturation potentials caused by aging of the electron discharge device is effectively nullified.

In accordance with the invention, in one of its preferred embodiments, a pair of electron discharge devices, which may take the form of pentode or beam-power tetrode vacuum tubes, are arranged with the usual resistance-capacitance cross coupling between the anode of each tube and the control-grid electrode of the other tube to form a conventional multivibrator oscillator. The biasing potential for each control-grid electrode is made variable with changes in the magnitude of the anode potential source. Also, it is so proportioned with respect to the anode potential supply that the voltage changes that are injected into the control electrode circuit of the oscillator substantially offset and cancel the effect of the voltage changes that are injected through the anode circuit of the oscillator, when the anode potential source varies in magnitude. In this manner, although the variations in the circuit potentials are not actually eliminated, their effects are nullified. In addition, certain of the circuit potentials are controlled in such manner that the cut-off potential and the voltage drop in the saturated anode-cathode discharge path of each tube are made variable, and each assumes a minimum value that is near zero during that portion of the oscillation cycle in

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which changes in its value would be reflected in changed oscillation characteristics.

A more complete understanding of the invention and the manner in which the foregoing objects are accomplished may be obtained from the following description of two embodiments thereof, when considered in conjunction with the drawing, in which:

Fig. 1 is an explanatory graph of the variations in potential on the control electrode of one electron discharge device of a multivibrator. Reference is made to this graph in the following description;

Fig. 2 is a schematic circuit diagram of a multivibrator oscillator in accordance with the present invention which is stabilized against frequency variations arising from changes in the magnitude of the anode potential supply; and

Fig. 3 is a schematic circuit diagram of a multivibrator oscillator in accordance with the invention in which the oscillation characteristic is stabilized against changes arising both from variations in the anode potential supply and from variations arising through changes in the electron discharge devices as they age.

In the following descriptions and in Figs. 2 and 3 of the drawing, like reference characters have been used to denote the same or similar circuit elements.

A more complete understanding of this invention may be had if it is first noted that several conditions contribute to instability of the oscillation frequency in the conventional relaxation oscillator of the multivibrator type. In general, the oscillation frequency is largely determined by the time constants of the inter-electrode coupling circuits of the oscillator. To a lesser, but still considerable degree, the frequency is also determined by the magnitude of the potential supply source, the load impedance, and the characteristics of the electron discharge devices or tubes themselves. Of these last-named factors, variations in the first are likely to occur at any time in the operating cycle, while variations in the last tend to occur primarily as aging of the tube progresses. It is thought that these factors affect the oscillation frequency of the oscillator through the variations that they introduce into the tube's cut-off potential value E_{co} , the magnitude of the voltage drop in the anode-cathode path of the tube when it is saturated, and the potential at which the control electrode of the saturated tube rests in the instant before that tube changes to its cut-off condition. The interrelation of these factors,

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and the manner in which they are controlled through the practice of this invention, may be best understood if the explanatory grid potential wave form diagram of Fig. 1 is first considered, together with the multivibrator oscillator circuit of Fig. 2.

Although in the following discussion the above-mentioned factors will be described as affecting only the potential change on control grid 11 of electron discharge device 10, it will be understood that they exert exactly the same influence on the potential of control-grid electrode 13 of discharge device 12. Therefore, variations in these factors are effective in causing variations in the oscillation frequency through the control that they exert in each of the electron discharge devices.

Fig. 1 is a graphical representation of the various circuit potential differences that influence the oscillatory period of the oscillator. It also forms a convenient basis for understanding how the stabilization of the oscillator against the effect of changes in the anode potential supply is accomplished. In this figure, t_1 indicates the cut-off interval of discharge device 10 (see Fig. 2), which interval it is desired to maintain constant; E_1 indicates the difference in potential between a suitable reference potential, such as ground, and the potential of the anode when the discharge device or tube 12 is saturated; E_2 indicates the difference in potential between this same reference potential and that of the control electrode of tube 10 just prior to the time that this tube is cut off; the broken line E_{co} indicates the value of the cut-off potential of electron discharge device or tube 10 for the designed operating conditions; E_p denotes the total potential difference that is available for affecting the momentary potential of control electrode 11 and is numerically equal to the negative value of the anode or plate potential source or battery 18; KE_p denotes the potential to which the control-grid electrodes are connected, and which they would tend to assume if current conduction were not started in the electron discharge device when its control-grid electrode acquired a potential in excess of E_{co} ; and (o) indicates the actual ground and cathode potential.

Referring now to Fig. 2, the electron discharge devices 10 and 12, which may suitably be pentode type vacuum tubes, together with the anode load resistors 14, 16; the coupling capacitors 20, 22; the grid resistors 24, 26; and the source of anode potential or battery 18, constitute a conventional multi-vibrator oscillator in which the control-grid electrodes 11 and 13 are connected to a point of potential that is positive with respect to the associated cathode electrodes. This positive biasing potential is secured from the movable arm 31 of potentiometer 32, which potentiometer forms a voltage dividing network across the potential source or battery 18. In accordance with one feature of this invention, the arm of potentiometer 32 is so positioned that a fractional part, KE_p , of the anode supply potential E_p is supplied to the control electrodes 11 and 13 through grid leak resistors 24, 26. This supplied potential KE_p is critical, and is so proportioned that when added to the cut-off potential E_{co} a combined potential value E_b (Fig. 1) results. At the time of cut-off, the potential of control electrode 11 becomes E_a volts more negative than its cut-off value E_{co} . When the grid charging potential KE_p is properly chosen, the ratio E_b/E_a is a constant value for varying values of E_p .

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The optimum value of potential KE_p is secured by properly positioning the movable arm of potentiometer 32, and it may be recognized by the fact that if KE_p is less than its optimum value, the frequency of oscillation varies inversely with an increment of potential change in anode potential source 18; that is, an increase in the potential of source 18 results in the lowering of the oscillation frequency. Conversely if KE_p is greater than its optimum value, the frequency of oscillation varies directly with changes in the potential of source 18. The actual value of the optimum grid charging potential KE_p will vary as the circuit parameters are changed. However, for each circuit configuration there is one distinct value of biasing potential KE_p for which the ratio E_b/E_a (Fig. 1) remains constant for all reasonably expectable potential changes in the anode potential supply E_p .

The manner in which the proper adjustment of the control grid charging potential KE_p introduces the desired compensatory effect may be best understood if the operation of the circuit (Fig. 2) is examined at a time just prior to and at the time that electron discharge device 10 changes from its saturated-current condition to its cut-off condition. At the time just prior to being cut off, discharge device 10 is saturated; its control grid 11 is resting at a potential E_2 , which may be slightly in excess of ground potential. At the instant of cut-off, the potential on control electrode 11 descends E_a volts below its cut-off potential to a value 50 that is determined by the charge then existing across coupling capacitor 22 and the change in potential at the anode of the now conducting device 12. This potential 50 is numerically equal to the anode supply potential E_p minus the combined residual potentials E_1 and E_2 , these latter being the potential difference between the anode and cathode electrodes of the saturated device 12 and the potential on control electrode 11 during the current saturation period of device 10, respectively. After being driven negatively, the potential on control electrode 11 increases as capacitor 22 charges until a potential of E_{co} is reached, at which time conduction is again started in device 10. This potential excursion E_a may be evaluated as:

$$E_a = E_p - E_1 - E_2 - E_{co}$$

If current conduction were not started in device 10 when its control electrode acquired the potential E_{co} and capacitor 22 continued to charge, the potential on control electrode 11 would become asymptotic to the biasing potential KE_p , as denoted by the dotted line 54. This would represent a further voltage excursion:

$$E_b = KE_p + E_{co}$$

Therefore, as the potential of control electrode 11 rises from its most negative point or value 50 to its cut-off potential E_{co} at point 52, it follows the exponential condenser charging curve evaluated as $e_{p10} = KE_p - (E_p + KE_p - E_1 - E_2) e^{-t/T}$ where T represents the time constant of capacitor 22 and resistor 24 (Fig. 2). If e_{p10} is equated to the cut-off potential $-E_{co}$, the cut-off interval t_1 of device 10 may be evaluated as:

$$t_1 = T \log_e \frac{[E_p(1+K) - E_1 - E_2]}{(KE_p + E_{co})}$$

From this explanation, it will be seen that the cut-off interval t_1 will remain constant notwithstanding variations in the anode potential supply

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E_p if the resultant changes that are introduced into potentials E_1 , E_2 , and E_{co} are caused to be compensatory, or if E_1 , E_2 , and E_{co} are caused to have zero values. In the circuit configuration shown in Fig. 2, the first of these conditions, namely, that the caused variations in potentials E_1 , E_2 , and E_{co} are compensatory is brought about by the proper proportioning of the control grid biasing potential KE_p in the manner which has been described. In this (Fig. 2) arrangement, the variations that are introduced into potentials E_1 , E_2 , and E_{co} by changes in the anode potential supply 18 may or may not be proportional. It is not necessary that they be proportional; it is only necessary that the effect of these variations be compensating in such manner that the above-mentioned logarithmic quantity maintains a constant value. This compensating condition is obtainable in each case when the grid biasing potential KE_p is suitably chosen.

In the circuit arrangement of Fig. 3, increased frequency stability is obtained by combining the previously described arrangement with a further improvement. The variations in potentials E_1 , E_2 , and E_{co} , caused by changes in the anode potential supply, are made compensatory through the proper choice of the grid biasing potential KE_p , while at the same time the potentials E_1 and E_{co} are caused to have a minimum value during that portion of the operating cycle of each electron discharge device 10 or 12 during which they exert a controlling influence on the oscillation frequency. Since these latter potentials are caused to assume minimum values approaching zero value, any variations in them will necessarily also be small, and the disturbing effect of such variations will be minimized if not completely eliminated.

In the circuit arrangement of Fig. 3, like reference characters are used to denote circuit elements that are the same as or similar to those shown in the multivibrator circuit of Fig. 2. It will be noted that the portion of the circuit comprising electron discharge devices 10 and 12 is substantially the same as in Fig. 2, with the exception that the screen grid potentials for these devices are made variable instead of being fixed quantities as in the former case. As in the former case, the control-grid electrode biasing potential KE_p is secured at the movable arm 31 of potentiometer 32. Each screen-grid electrode is biased from a variable voltage-dividing circuit comprising resistor 28 or 30 and the anode-cathode discharge path of an auxiliary electron discharge device 34 or 36, each of which may suitably be a pentode-type vacuum tube or other suitable controllably variable impedance element. The screen electrode potential for auxiliary devices 34, 36 is obtained through a suitably proportioned resistor 35 from the anode potential source 18. The control electrodes 33, 37 of these devices are connected through capacitors 38, 39 to the anodes of discharge devices 10 and 12. Grid-leak resistors 40, 44 are also connected to these control electrode circuits and are of such magnitude that time-constant circuits which are long relative to the oscillation period of tubes 10 or 12 result from their combination with the respective capacitors 38, 39.

The manner in which the multivibrator type of oscillator of Fig. 3 operates to achieve increased frequency stability will be better understood if it is recalled that the saturated current conduction condition of one oscillator tube coincides with the current cut-off condition of the other tube, and

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vice versa. It should also be recalled that variations in the potential difference E_1 between the anode and cathode electrodes in the saturated tube are effective in influencing the oscillation frequency during the same portion of the cycle that variations in the cut-off potential value E_{co} are effective in the non-conducting or cut-off tube.

From the previously described circuit relations it will be recalled that the cut-off interval t_1 is evaluated:

$$t_1 = T \log_e \frac{[E_p(1+K) - E_1 - E_2]}{(KE_p + E_{co})}$$

It is, therefore, evident that increased stability in the cut-off interval t_1 will result if in addition to causing the variations in potentials E_1 , E_2 and E_{co} to be compensatory (as was described in connection with Fig. 2) the potentials E_1 and E_{co} are caused to assume minimum values near zero during that portion of the oscillation cycle in which they exert a controlling influence. These combined stabilizing influences are realized in the multivibrator type of circuit of Fig. 3 through the combination of the compensating adjustment of the control electrode potentials, and the action of the variable impedance elements, pentodes 34, 36, on the screen electrode potentials of oscillator tubes 10, 12.

Both E_1 and E_{co} are greatly influenced, but in opposed directions, by changes in the magnitude of the screen electrode potential. That is, an increase in this potential reduces the potential difference E_1 between the anode and cathode electrodes of the tube while it is in its saturated condition, which is desirable; but it also increases the cut-off potential E_{co} , which is undesirable. Since E_1 and E_{co} exist simultaneously but in different tubes, it is possible to reduce each to a minimum at the same time by properly controlling the screen electrode potential of the respective tube. Accordingly, separate screen electrode biasing circuits including variable impedance devices 34, 36 are provided for the electron discharge devices 10 and 12. When electron discharge device or tube 10 changes from its full conduction to its cut-off condition, a positive voltage impulse is coupled from its anode circuit through coupling capacitor 38 to control electrode 33 of the variable impedance device or pentode 34. The time constant of capacitor 38 and resistor 44 is large, and this positive voltage impulse persists on electrode 33 for the duration of the cut-off interval t_1 to lower the impedance of the discharge path of pentode 34; and thereby lower the potential of the screen electrode of device 10. This lowered screen electrode potential reduces the cut-off potential E_{co} to a minimum value which may be made to be zero or thereabouts. Any changes in the anode potential supply E_p or in the spacing of the elements of discharge device 10, which change would normally tend to affect the cut-off potential E_{co} , are ineffective in asserting a controlling influence since the cut-off potential has been reduced to zero or near zero value.

At the same time that device 10 changes to its cut-off condition, device 12 becomes fully conductive with an attendant potential drop at its anode. This potential drop is coupled through capacitor 39 to reduce the potential of control electrode 37 of the auxiliary pentode 36, and thereby increase the impedance of the anode-cathode discharge path of this auxiliary pentode. This increased impedance increases the potential on the screen electrode of device 12, which

change decreases the voltage drop E_1 in the saturated anode-cathode discharge path of device 12 to a minimum value that is considerably less than it would be if the screen electrode potential were not increased. Because of the minimum value condition, the effect of variations in circuit potentials or structures, which variations would normally influence or change the anode-cathode potential difference, is eliminated or at least minimized.

The action of the auxiliary discharge devices 34, 36 is thus seen to be to increase the screen electrode potential of the saturated oscillator tube and thus lower the voltage drop in its anode-cathode discharge path, while at the same time the screen electrode potential of the cut-off or non-conducting device is lowered and the cut-off potential E_{co} of this device is reduced to a minimum value.

In addition to the stabilizing action of the auxiliary pentodes 34, 36, it will also be understood that the selection of the optimum biasing potential KE_p for the control grid electrodes 11 and 13 of devices 10 and 12 imparts a stabilizing effect against variations caused by changes in the magnitude of the anode potential supply 18. The correct positioning of the movable arm 31 of potentiometer 32 to secure this optimum biasing potential KE_p is performed in the manner previously described in connection with Fig. 2. The empirical method for determining the correct position of this potentiometer arm may be performed as described, but the actual value of KE_p will usually be found to be different in the arrangements of Figs. 2 and 3 because of the revised conditions that govern the potentials E_1 and E_{co} in the latter arrangement.

In general, the most satisfactory method of stabilizing the described type of oscillator will employ both the choice of an optimum value of biasing potential KE_p and the use of variable screen electrode potentials on the oscillator tubes. Through the combined use of these stabilizing factors, an extremely high degree of frequency stability may be achieved. However, it should be appreciated that this invention is not limited to only the combination of these two stabilizing factors, since a material but lesser improvement in the stability of the oscillator may be secured through the use of only variable screen electrode potentials on the oscillator tubes.

Although this invention has been described as being incorporated in a specialized type of oscillator, it will be evident to those skilled in the art that it is not limited in its application to the described arrangements. Therefore, it is to be expected that variations of this invention, which do not depart from its spirit and scope, will suggest themselves to those skilled in the pertinent art.

What is claimed is:

1. A stabilized multivibrator type oscillator comprising a first and a second pair of electron discharge devices, each of said devices comprising anode, cathode, control grid and screen grid electrodes, a source of positive potential resistively connected across the anode-cathode electrodes of each of said devices, a capacitive coupling between the anode and electrode of each one and the control grid electrode of each other one of said first pair of devices, grid-leak resistors connected in the control grid cathode circuit of each of said devices, the screen grid electrode of each of said first pair of devices being connected to the anode-electrode of a respective one

of said second pair of devices, and a capacitive coupling connecting the anode electrode of each of said first pair of discharge devices and the control grid electrode of the same respective one of said second pair of devices.

2. A stabilized multivibrator type oscillator comprising a pair of electron discharge devices each including an anode, a cathode, a control grid and a screen grid electrode, a source of potential, an individual resistive connection between the positive terminal of said potential source and each of said anode and said screen grid electrodes, cross-couplings between the anode and each device and the control grid electrode of each other device, a grid-leak resistor in the control grid cathode circuit of each device, an individual variable impedance connected between the negative terminal of said potential source and the screen grid electrode of each of said discharge devices, and means connected to the anode of each discharge device to control the magnitude of the impedance connected to the screen electrode of said device in inverse relation to the changes in potential of said anode.

3. A stabilized multivibrator type oscillator comprising a pair of electron discharge devices, each of which includes an anode, a cathode, a control grid and a screen grid electrode, a source of potential having positive and negative terminals, a load impedance connected between said positive terminal and each of said anodes, a grid-leak resistor connected between each control grid electrode and a point of potential positive with respect to said cathodes, each of which is connected to said negative potential terminal, a pair of voltage dividing circuits each connected between said positive and negative terminals and each comprising a fixed and a variable impedance element in series connection, each of said screen grid electrodes being connected to an intermediate point on a respective one of said divider circuits and a coupling between each anode electrode and the variable impedance element connected to its conjugate screen grid electrode whereby the impedance of said element is changed as the potential of said anode is changed.

4. A stabilized multivibrator type oscillator in accordance with claim 3 in which the impedance of said variable impedance element is increased as the potential of said anode is decreased and vice versa.

5. A stabilized multivibrator type oscillator comprising a pair of electron discharge devices, each of which includes an anode, a cathode, a control grid and a screen grid electrode, a source of potential having a positive and a negative terminal, a load impedance connected between said positive terminal and each of said anodes, a grid-leak resistor connected between each control grid electrode and its associated cathode electrode, which latter is connected to said negative potential terminal, a pair of voltage dividing circuits connected between said positive and said negative terminals each circuit comprising a fixed and variable impedance element in series connection, said variable element including the anode-cathode discharge path of an auxiliary electron discharge device which device includes a control grid electrode, a connection between each of said screen grid electrodes and an intermediate point on a respective one of said divider circuit, and a capacitive coupling between each of said anode electrodes and the control grid electrode of the auxiliary discharge device that is connected to its conjugate screen grid electrode

whereby the potential of said auxiliary control grid electrode is increased and the impedance of the auxiliary device's anode-cathode path is decreased as the potential of the connected anode of said first-mentioned device is increased, and vice versa.

6. A stabilized multivibrator type oscillator comprising a pair of electron discharge devices each of which includes an anode, a cathode and a screen grid electrode, a source of current, said source including positive and negative terminals, a load impedance connected between said positive terminal and each of said anodes, a connection between each of said cathodes and said negative terminal, a grid-leak resistor connected between each control grid electrode and its associated cathode, a pair of voltage dividing circuits connected in parallel between said positive and negative terminals, each of said circuits comprising a fixed resistance and the anode-cathode path of an auxiliary discharge device, which device includes a control grid electrode, a connection between each of said screen grid electrodes and an intermediate potential point on a respective one of said divider circuits, a capacitive connection between the anode-cathode circuit of each of said pair of discharge devices and the control grid electrode of a respective one of said auxiliary discharge devices, whereby the impedance of the anode-cathode path of said auxiliary device is varied in accordance with changes in the magnitude of the current flowing in the anode-cathode circuit to which its control electrode is connected.

7. A stabilized multivibrator type oscillator comprising a pair of electron discharge devices each including an anode, a cathode, a control grid and a screen grid electrode, anode-cathode circuits including a source of anode potential and control grid cathode circuits therefor, cross-couplings between the anode-cathode circuit of each device and the control grid cathode circuit of the other device, an impedance connection between said source and each of said screen grid electrodes, and means for controlling the potential on each of the screen grid electrodes in accordance with the magnitude of the current flowing in its associated anode-cathode path, said means comprising an auxiliary discharge device respective each screen grid electrode, said auxiliary device including an anode, a cathode and a control grid electrode, a first connection between each of said screen grid electrodes and the anode of the respective auxiliary device, and a second connection between the anode-cathode circuit of each of said first-mentioned devices and the control grid cathode circuit of a respective one of said auxiliary devices.

8. A multivibrator type relaxation oscillator comprising a pair of electron discharge devices each including an anode, a cathode, a control

grid and a screen grid electrode, a source of positive potential, means comprising a plurality of resistive connections for supplying positive potential from said source to said anode and said screen grid electrodes, a direct connection from said cathodes to the negative terminal of said potential source, means comprising a pair of resistive connections for supplying a lesser positive potential from said source to each of said control grid electrodes, a pair of auxiliary electron discharge devices each of said devices comprising an anode, a cathode and a control grid electrode, a connection between the screen grid electrode of each of said first-mentioned discharge devices and the anode of a respective one of said auxiliary devices, and a capacitive coupling between the anode of each of said first-mentioned devices and the control grid electrode of the respective connected auxiliary discharge device.

9. A relaxation type of oscillator comprising a pair of electron discharge devices each including an anode, a cathode, a control grid, and a screen grid electrode, a source of positive potential, a resistive connection between each anode electrode and said source, a resistive connection between each screen grid electrode and said source, a capacitive coupling between the anode of each discharge device and the control grid electrode of the conjugate device, conductive connections between each control grid electrode and said source of positive potential, and means for controlling the potential of the screen grid electrode of each discharge device in accordance with the current conducting state of said device, said means comprising an auxiliary electron discharge device respective each of said first-mentioned devices, said auxiliary device having anode-cathode and control grid cathode circuits, said anode-cathode circuit being connected from the screen grid electrode of the respective first-mentioned discharge device to the negative terminal of said source of positive potential, and said control grid cathode circuit being coupled to the anode electrode of said respective first-mentioned discharge device.

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