

Nov. 11, 1941.

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2,262,468

THERMIONIC VALVE CIRCUIT

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3 Sheets-Sheet 1

Fig. 6.

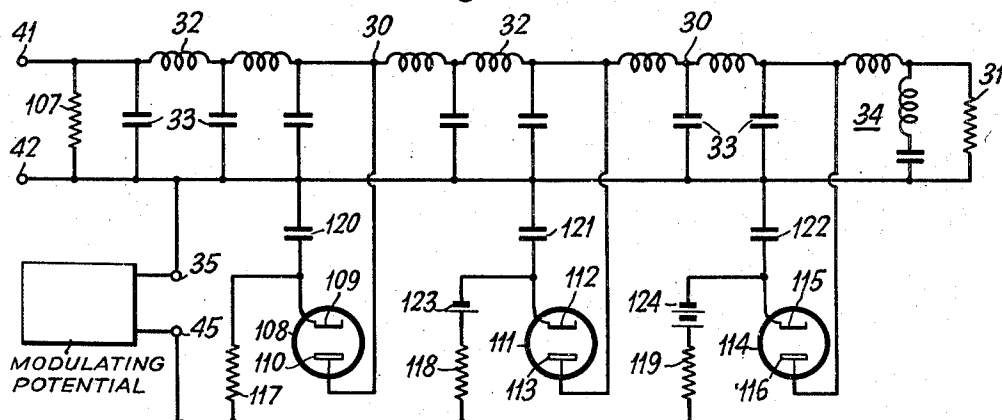
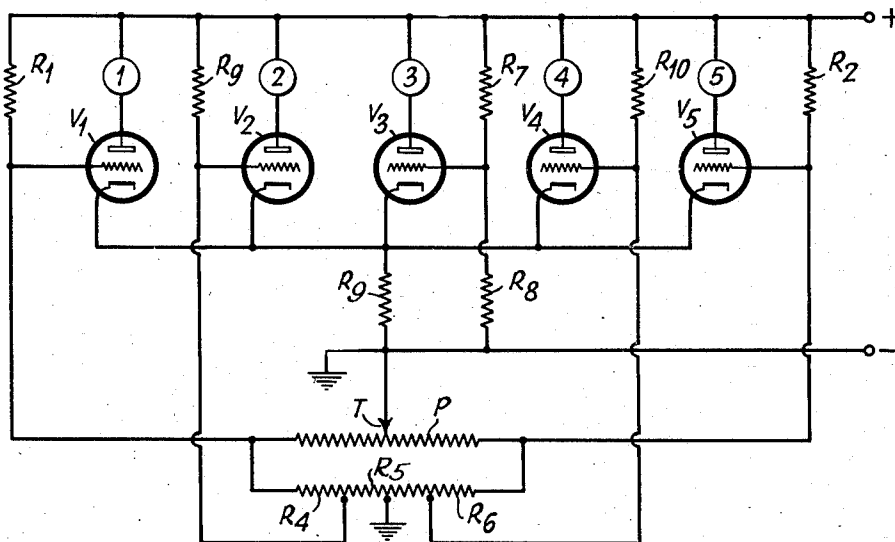


Fig. 1.



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Fig. 4.

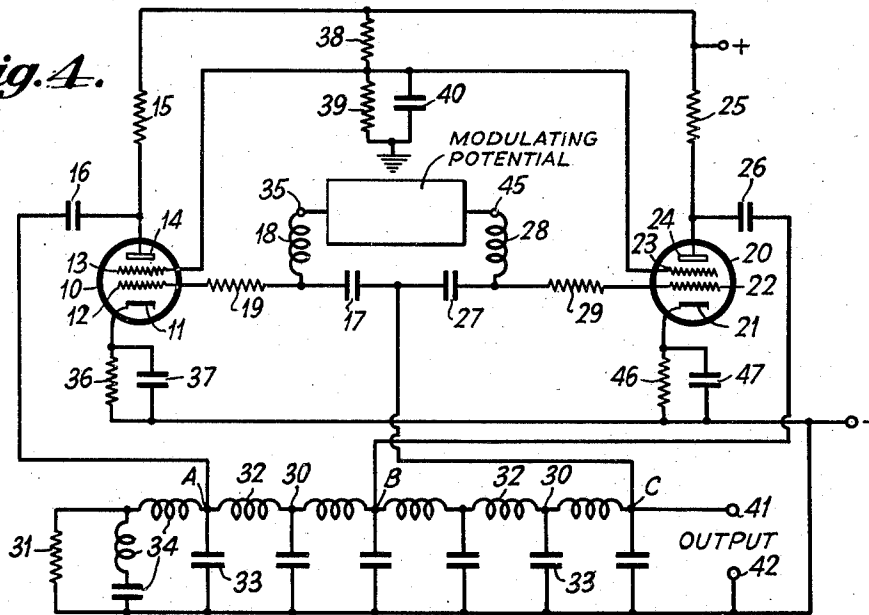
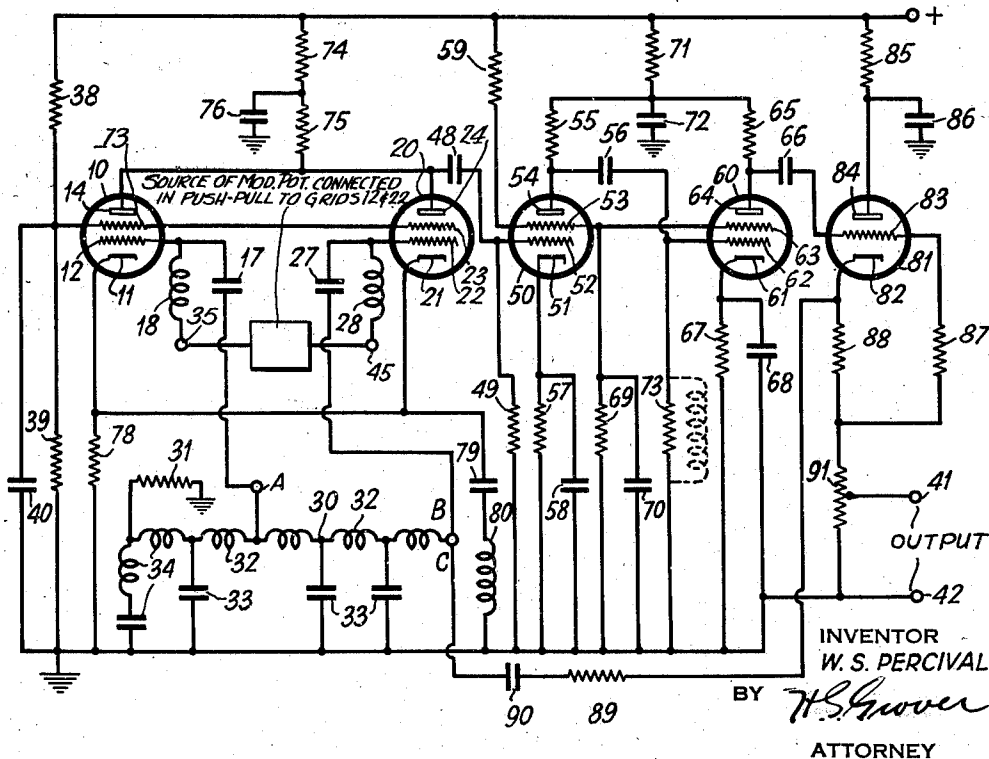


Fig. 5.



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THERMIONIC VALVE CIRCUIT

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11 Claims. (Cl. 179—171.5)

The present invention relates to thermionic valve circuits and has particular reference to thermionic valve switching arrangements. In addition the invention relates to the use of such thermionic valve switching arrangements in frequency or phase modulated radio transmitters.

It is an object of the present invention to provide means whereby a number of thermionic valves can be turned on and off in turn in a predetermined manner. According to the invention a thermionic valve circuit is provided comprising three or more valves and means for applying switching signals to said valves so as to cause them to assume conducting or non-conducting conditions in a predetermined order, wherein said valves are so arranged that the sum of cathode currents which can be passed by said valves tends to remain at a constant value so that on the application of said switching signals at least one of said valves is prevented from assuming a conducting condition.

According to a feature of the present invention a frequency modulating system is provided employing a thermionic valve circuit operating according to the preceding paragraph wherein each of said valves is so arranged as to tend to generate oscillations of substantially different frequencies and said switching signals comprise modulating potentials which force said valves to produce oscillations of a resultant frequency, the amplitude of the modulating potentials determining the resultant frequency of the generated oscillations.

Other features of the invention will appear from the following description and the appended claims.

The invention will be described by way of example with reference to the accompanying drawings in which

Figure 1 illustrates an embodiment of the invention,

Figure 2 is an explanatory drawing, and

Figure 3 represents a further embodiment of the invention as applied to a frequency or phase modulating system.

Figures 4, 5 and 6 are modifications of the frequency modulator systems illustrated in Figure 3.

Figure 1 shows a circuit for the control of five valves, the control being affected by a potentiometer P for simplicity, and the anode circuits being indicated respectively by ringed numerals 1-5. All five valves V_1 , V_2 , etc., have a large common cathode resistance R_3 which is connected to the negative side of a source of anode potential not shown. The resistance R_3 in the common

cathode tends to maintain the current flowing through the valves constant. The resistance R_3 may be replaced by any other suitable impedance, as for example, an inductance. The variable tapping T on the potentiometer P is also connected to the negative side of the source of potential and to earth. R_1 and R_2 are equal dropping resistances connected between the positive side of the potential source and the grids of valves V_1 and V_5 respectively. These two grids are connected to opposite ends of the potentiometer P. The resistances R_4 , R_5 and R_6 constitute together a potential divider in parallel with P with two fixed tapping points for the grids of V_2 and V_4 , the centre tap of R_5 being earthed.

The grid of the valve V_3 is biased by a suitable positive potential as determined by resistance R_7 and R_8 connected across the anode supply. Also the grids of V_2 and V_4 are supplied with suitable positive potentials by resistances R_9 and R_{10} . When tapping T is at the extreme right the biases are such that only valve V_1 passes current. When T is moved towards the left V_2 begins to pass current, and, as the total current tends to remain constant, this involves a reduction in the current of V_1 . As T is moved still further to the left the current of V_1 ceases and V_3 begins to pass current. When T is at the centre position only V_3 passes current. Finally with T at its extreme left position only V_5 passes current.

In practice it has been found that the values of the resistances may have to be adjusted to obtain the required changeover of current, say, from V_2 to V_3 without V_4 passing more than a very small current in the tapping position where V_2 ceases to pass current and V_3 passes its maximum current. If, however, it is assumed that the variation of anode current with grid bias is linear for all potentials to the cut-off potential, then it is possible to calculate the resistances required.

Assuming that the cut-off bias is V_0 volts and that the required maximum current for each valve is obtained at zero bias, and that the cathode potential is large compared with V_0 , then a change of V volts in the grid potential of V_1 serves to back this valve off completely so that V_2 passes its maximum current. This means that the grid bias of V_1 has been increased V_0 volts with reference to its cathode, while that of V_2 has been decreased V_0 volts with reference to its cathode, which is at the same potential as the V_1 . This implies that the cathode potential has changed by $V-V_0$ volts and the grid potential of V_2 has changed by an amount of $V-2V_0$ volts. When V_2 is in turn passing zero current and V_3

is passing maximum current, the grid potential of V_2 will have changed by a total amount $V-2V_0+2V_0=V$ volts, since the grid potential of V_3 is constant, but the cathode potential will have changed by V_0 volts. Meanwhile, the grid potential of V_1 will have changed by $2V_0$ volts, but the total change of grid bias of V_2 must be twice $2V_0$, that is, $4V_0$ volts. Thus, $4=4V_0$.

These changes are shown in Figure 2, together with the changes for V_4 and V_5 . It will be noticed in this figure that the slope of $Vg2$ and $Vg4$ is half that of $Vg1$ and $Vg5$. Hence $R_5=2R_4$ if R_4 and R_{10} are assumed to be large. It will be noticed that when the tapping T is at the extreme right of potentiometer P , the potential on the grid of valve V_1 is as indicated at the point K . Since the cathode potential curve V_c intersects the $Vg1$ curve at point K it will be seen that V_1 takes the maximum current at this point. When tapping T reaches the point on the potential divider equivalent to M the potential between cathode and grid of V_1 is equivalent to LM , which represents V_0 ; in other words, V_1 ceases to pass current. At this point the grid cathode potential of V_2 is zero and thus V_2 passes the maximum current. At point N , V_2 is cut-off because NR represents V_0 , but V_3 takes the maximum current because the grid-cathode potential is now zero; and so on for the remaining valves. It will be understood that this argument can be extended to more than five valves.

In Figure 1 certain simplifications have been introduced. In practice, modulation potentials may be applied across the ends of the potentiometer P , and the tapping T may be fixed in the centre of P .

The switching circuit of the present invention has particular application to frequency or phase modulation circuits and in order to explain the operation of such a switching circuit as applied to a frequency modulated radio transmitter, reference should be made to Figure 3 of the accompanying drawings.

Referring to Figure 3, three screen grid valves 10, 20 and 92, have their anodes 14, 24 and 96 connected by the condensers 16, 26 and 99 to the points A , B and D on a delay network 30, which comprises series inductances 32 and shunt condensers 33. The delay network 30 is terminated at one end by means of the terminating resistance 31 and an m -derived section 34. The control grids 12, 22 and 94 of the three valves are connected effectively in parallel as regards carrier frequencies by means of condensers 17, 27 and 97 to a common point C on the end of the delay network remote from the terminated end. The screening grids 13, 23 and 95 of the three valves are suitably decoupled and provided with positive potentials by means of resistances 38 and 39 and condenser 40. Resistance 100 forms the grid leak for biasing valve 92. The anode impedances 15, 25 and 98 of the three valves 10, 20 and 92 are suitably decoupled by means of resistance 74 and condenser 76. A common cathode resistance 78 is employed for all the valves so that the sum of the currents at modulation frequencies taken by the three valves tends to remain substantially constant. The acceptor circuit 79, 80, serves to earth the cathodes for carrier frequencies. The modulation potentials are applied via terminals 35 and 45 in anti-phase to the grids 12 and 22 of valves 10 and 20 through H. F. chokes 18 and 28, the biases of the valves being so adjusted that with the application of peak modulating potentials either valve 10 or valve 20 only is operative,

whereas with zero applied modulating potentials only valve 92 is operative.

The operation of the circuit can be explained as follows:

5 Assume that the terminal 35 is made positive and the terminal 45 is made negative so that only valve 10 is conducting. Owing to the presence of the delay network of length AC between the anode and grid circuits of valve 10 this valve will oscillate at a frequency f_1 at which the time delay between A and C is equal to the half period, that is, there is a phase change of 180° in the delay network.

10 If now valve 10 is biased off completely, and only valve 20 is permitted to conduct, then the latter valve will oscillate at a frequency f_2 such that the time delay BC is equal to a half period. Similarly, if only valve 92 is conducting, the frequency f_3 at which valve 92 oscillates, is determined by the length CD of the delay network 30. Should both valves 10 and 92 be conducting simultaneously, then if the ratio of the two periods AC and CD is not too great, for example, not more than about 1.5 to 1, then oscillation will occur at a resultant frequency intermediate f_1 and f_3 , the actual frequency depending on the relative currents taken by the two valves. Thus, the effect of modulation applied between the two terminals 35 and 45 is to make the frequency vary in sympathy between the two extreme limits f_1 and f_3 .

The shunt capacities of the delay network at A , B , C and D may be reduced to allow for the valve capacities and stray capacities in parallel. In the extreme case these capacitances may consist entirely of the valve and stray capacities. If the capacity of the three grids in parallel is too high, then the grids may be separately connected across adjacent sections of the network. The output of the oscillator may be taken from terminals 41 and 42.

As shown, the delay network is terminated by an m -derived section indicated at 34 to prevent undesirable deflection. It is not essential to terminate at the other end of the filter if the grids are connected at this point. If, however, the grids are not connected at, or near, the open end of the delay network, then it is desirable to terminate the network at both ends to prevent reflected oscillations producing on the grids of the valves additional impulses which may change the frequency of oscillation. In this connection it may be desirable to insert resistances in the grid leads in order to cause the gain of the valves to fall off with frequency in order to prevent oscillations occurring at a frequency in the neighbourhood of the cut-off of the filter.

Although the circuit described in Figure 3 is intended primarily for frequency modulation, it will be obvious that by omitting the feedback path and thus preventing oscillation and by supplying a carrier frequency to the modulated valves, which then act as radio-frequency amplifiers, the circuits can be adapted for phase modulation. For example, in Figure 3, the lead between C on the delay network and the condenser 27 may be disconnected and a carrier frequency applied to the condenser 27. The phase modulated signals are then derived from 41 and 42.

It will be understood that although the main object of the circuit of Figure 3 is to produce large variations of frequency or phase for frequency or phase modulation, the circuit described can be used for other purposes, such as the remote control of the oscillator frequency

of a superheterodyne radio receiver, etc. One special application is to provide saw-tooth frequency variations for showing the response curve of a television receiver on the screen of a cathode ray tube. By reducing the feedback in the circuit below the point at which oscillation occurs, the circuit may be used for so-called resistance tuning, i. e. tuning which is not performed by varying a capacity or an inductance.

Referring to Figure 4 which shows a circuit for frequency modulation according to the invention, 10 and 20 are two oscillator valves to which modulation frequencies are applied between terminals 35 and 45 in anti-phase to the two grids 12 and 22 respectively. The anodes 14 and 24 of the two valves are joined to a source of positive potential by means of anode resistances 15 and 25. The anode 14 of valve 10 is connected through a blocking condenser 16 to a tapping A on a delay network 30, and similarly the valve anode 24 is connected via condenser 26 to a different tapping B on the network, the latter being terminated at one end by a terminating resistance 31. The open end G of the delay network is taken to the junction of two condensers 17 and 27, which are connected through resistances 19 and 29, to the respective grids of valves 10 and 20. These condensers function as high impedances for the modulation frequencies and low impedances for the carrier and sideband frequencies. Chokes 18 and 28 are designed to have a low impedance for the modulation frequencies and a high impedance for the carrier and side-band frequencies. The two valves are biased by means of the usual cathode resistances 36 and 46 and by-pass condensers 37 and 47. The screen grids 13 and 23 are supplied with positive potentials by means of the potentiometer comprising resistances 38 and 39, condenser 40 being for by-passing purposes. The radio-frequency output can be taken from terminals 41 and 42 connected across the open end of the delay network, which comprises series inductances 32 and shunt capacitances 33. The anode resistances 15 and 25 should be large compared with the characteristic impedance of the low-pass delay network.

The operation of the circuit can be explained as follows: Let the valve 20 be biased so completely so that only valve 10 is effective. The valve 10 then oscillates at a frequency f_1 , at which the time delay between A and C is equal to the half period, i. e., there is a phase change of 180 degrees in the delay network. Oscillations would also occur at other higher frequencies if it were not for resistance 19, which causes the gain to fall off with frequency. In practice it may be found that the oscillation is rich in harmonics, but this is not a disadvantage.

If, now, valve 10 is biased off completely instead of valve 20, then the latter oscillates at a frequency f_2 such that the time delay BC is equal to a half period. If both valves are passing current and the ratio of the two periods AC and BC is not too great, for example, not more than 1.5:1, then oscillation will occur at an intermediate frequency. Thus, the effect of modulation applied between the two grids is to make the frequency vary in sympathy between the extreme limits f_1 and f_2 .

It is desirable that the valves 10 and 20 be matched. This is not so necessary, however, if a common cathode impedance is employed, which is large at the modulation frequencies but small at the frequencies of the carrier and sidebands.

Such an impedance causes the sum of the currents through the valves to vary only slightly at modulation frequencies. Thus, the effect of a mis-match between the valves is reduced to a second order.

The shunt capacitances of the delay network at A, B and C may be reduced to allow for the valve capacities and stray capacities in parallel. In the extreme case those capacitances may consist entirely of the valve and stray capacities. If the capacity of the two grids in parallel is too high then the grids may be separately connected across adjacent sections of the network.

As shown, the delay network is terminated by an m -derived section, indicated at 34, to prevent undesirable reflection. It is not essential to terminate the network at the other end of the filter if the grids are connected at this point. If, however, the grids are not connected at, or near, the open end of the delay network then it is desirable to terminate the network at both ends to prevent reflected oscillations giving the grids additional impulses which may change the frequencies of oscillation. Although resistances 19 and 29 are shown in the grid leads in order to cause the gain to fall off with frequency, any other suitable means may be employed for this purpose, as for example, the shunt capacitance at C may be increased.

To increase the mean working frequency, it is desirable to employ a low-pass filter of low characteristic impedance. It may be found that when this impedance is low enough, that there is insufficient gain for oscillation. In such a case additional amplifying valves may be employed. The use of such additional valves increases the flexibility of the arrangement.

A suitable circuit employing five valves is shown in Figure 5. In this figure, the valves 10 and 20 are again arranged to be modulated in anti-phase. A common cathode biasing arrangement, comprising resistance 78, condenser 79 and inductance 80, is employed in this circuit for reasons already given. Valves 50 and 60 are amplifying valves and valve 81 is a cathode follower valve, the cathode impedance 88 and 91 of which serves as the main matching impedance of the delay filter. A common anode resistance 75 with suitable decoupling resistance 74 and condenser 76 is provided for the valves 10 and 20. The anodes of these valves are coupled through condenser 48 and grid resistance 49 to the grid 52 of valve 50. The potentiometer comprising resistances 59 and 69 and by-pass condenser 70 supplies a suitable positive potential to the screen grids 53 and 63 of valves 50 and 60, which have separate cathode biasing circuits comprising resistances 57 and 67 and condensers 58 and 68. Valves 50 and 60 have separate anode resistances 55 and 65 and a common decoupling resistance 71 and condenser 72. The anode 54 of valve 50 is coupled via condenser 56 and grid resistance 73 to the grid 62 of valve 60. Similarly, the anode 64 of valve 60 is connected to the grid 83 of valve 81 by means of the condenser 66 and resistance 87. The cathode follower valve has an anode decoupling circuit 85 and 86 and bias is obtained from the potential drop across resistor 88. The output can be taken from terminals 41 and 42 connected across the cathode resistance 91. The cathode 82 is connected to a tapping C on the network, which tapping is coincident with the tapping B. It has been found with this circuit that there is sufficient phase change in the amplifier to give oscillation without an additional

delay network between B and C. Thus, the frequency of oscillation depends substantially on the phase change due to the valve and stray capacities shunting the anode and grid resistances. The delay section from A to BC is, however in circuit when valve 10 only is operative. The frequency obtained with valve 10 alone is, therefore, the minimum frequency and that with valve 20 alone is the maximum frequency available. The additional inductance shown in shunt with resistance 73 has been found to raise the maximum frequency available and also to reduce amplitude modulation.

With the methods of modulation so far described, there is a definite limit to the ratio of the maximum frequency to the minimum frequency obtainable and with ratios above 1.5:1 there is a tendency to serious amplitude modulation. This limitation can be overcome by the use of more than two modulated valves as shown in Figure 3.

The circuit shown in Figure 6 illustrates a further method of frequency modulation. In Figure 6 a delay network 30 is shown with series inductances 32 and shunt capacitances 33 and terminated at 34, 31. At the end of the delay network remote from 31 is connected a negative resistance 107 across which the output terminals 41 and 42 are connected. Diode valves 108, 111 and 114 are connected across the delay network at separate tapping points, the cathodes 109, 112 and 115 of which are connected to terminal 42 by means of condensers 120, 121 and 122. The modulation frequencies are applied to terminals 35 and 45, and through the series isolating resistances 117, 118 and 119 to the cathodes 109, 112 and 115. Bias batteries 123 and 124 are provided for the diodes 111 and 114.

If the delay network is of lower characteristic impedance than the negative resistance, which may be a dynatron, and it is correctly terminated at the end remote from the negative resistance then oscillation will not take place, assuming that the diodes are out of circuit. If the delay network is shorted at the remote end then oscillation will take place at a frequency such that the delay from the negative resistance end of the filter to the shorted point is equal to a quarter of a period. Now, if a number of diodes are connected across different points on the delay network as shown and if the slope resistance of each diode is low compared with the characteristic impedance of the filter then the frequency of oscillation will be determined almost entirely by the position of the first diode 108 nearest to the negative resistance. As the first diode is gradually biased off the frequency of oscillation is determined mainly by the position of the second diode 111. As this second diode is in turn biased off the frequency of oscillation will be determined chiefly by the position of the third diode 114 and so on, if further diodes are employed. Thus, by applying modulation so that the diodes are biased off successively frequency modulation is obtained. By employing a sufficiently long delay network and sufficient diodes there is theoretically no limit to the range of frequency modulation that may be obtained. In the circuit shown the cathode of the second diode 111 is biased more than diode 108 and similarly diode 114 is biased more than diode 111, in order that the modulation shall bias the valves off successively.

A number of modifications of the arrangement will occur to one skilled in the art. The essential feature of the circuit described above is the

use of one or more valves to vary the effective length of a delay network and thus change the frequency of oscillation. By substituting the output of an amplifying valve for the dynatron, and applying a signal of fixed frequency, phase modulation can be obtained.

I claim:

1. In an electrical system, a plurality of valves each having a control electrode and output electrodes including a cathode, direct-current paths including said output electrodes for supplying anode-cathode direct-current for all of said valves, means for maintaining the sum of the anode-cathode direct current drawn by all of said valves substantially constant, a source of variable control potentials connected with the control electrodes of said valves for controlling the conductivity of said valves in a pre-determined sequence by varying the control electrode potentials whereby certain of said valves periodically drawn more current than other of said valves and vice versa, and an output circuit connected with said output electrodes.

2. A system as recited in claim 1 wherein said cathodes are tied together and said direct-current paths including said output electrodes have a common portion, and wherein said means for maintaining the sum of the cathode-anode current substantially constant is in said common portion.

3. In an electrical system, a plurality of valves each having a control electrode and output electrodes including a cathode, a potentiometer resistance energized by direct-current voltage, means for deriving from said resistance variable control potentials, said means comprising connections between the control electrode of each of said valves and a different point on said resistance, a connection tying the cathodes of said valves together and a connection between said last connection and a movable point on said resistance, whereby different biases are supplied to said control electrodes and certain of said valves are conductive and others less conductive and adjustment of said movable point on said resistance increases the conductivity of certain of said valves and decreases the conductivity of other of said valves, means in said last named connection for maintaining substantially constant the anode-cathode current drawn by said valves and an output circuit connected with the output electrodes of said valves.

4. In a signalling system, a plurality of valves each having a control electrode, an anode electrode, and a cathode, a line comprising series and shunt reactances, means connecting the control electrodes of said valves to a point on said line, means connecting the anode of one of said valves to a second point on said line, means connecting the anode of another of said valves to a point on said line intermediate said first two points, a direct-current circuit including the anode and cathode of each of said valves, means in said direct-current circuit for maintaining substantially constant the anode-cathode current drawn by said valves, means for modulating the impedances of a pair of said valves in phase opposition, and an output circuit connected with the output electrodes of said valves.

5. In a frequency modulation system a plurality of valves each having a control electrode and output electrodes including a cathode, a source of current for supplying anode-cathode current for all of said valves, means in the anode-cathode-direct-current path of between each of

said valves and said source for maintaining the sum of the anode-cathode current drawn by all of said valves substantially constant, oscillation generating circuits tuned to different frequencies regeneratively connected with the control electrodes of each of said valves for the production of oscillations of different frequency, and means for modulating the impedances of said valves at signal frequency to cause said valves to produce a common resultant frequency which varies at signal frequency within the range of frequencies produced by said individual valves.

6. In a wave length modulation system, a plurality of valves each having a control electrode, an anode and a cathode, a direct-current circuit including the anodes and cathodes of said valves for supplying anode-cathode current for all of said valves, means in said direct-current circuit for maintaining the sum of the anode-cathode currents drawn by all of said valves substantially constant, a source of modulating potentials connected with the control electrodes of certain of said valves for controlling the conductivity of said valves in a pre-determined sequence characteristic of the modulating potentials, whereby certain of said valves periodically draw more current than other of said valves and vice versa, a time delay circuit wherein wave energy to be modulated is caused to flow, means connecting the anodes of said valves to spaced points on said time delay circuit, and an output circuit connected to points on said time delay circuit.

7. In a frequency modulation system, a plurality of valves each having a control electrode, an anode, and a cathode, a source of direct current in a circuit including the cathode and anode of all of said valves, means in said direct-current circuit for maintaining the sum of the anode-cathode currents drawn by all of said valves substantially constant, a source of modulating potentials connected with the control electrodes of certain of said valves for controlling the conductivity of said valves in a pre-determined sequence characteristic of the modulating potentials, whereby certain of said valves periodically draw more current than other of said valves and vice versa, a time delay circuit comprising series and shunt reactances, connections between a point on said time delay circuit and each of said control electrodes, connections between spaced points on said time delay circuit and the anodes of said valves, and output terminals connected with said time delay circuit.

8. In a frequency modulation system, a plurality of valves each having a control electrode and output electrodes including an anode-cathode, a source of current connected in a cathode-direct current circuit including the cathodes of all of said valves, means in said direct-current circuit for maintaining the sum of the anode-cathode currents drawn by all of said valves substantially constant, oscillation generating circuits of different periodicity connected between the electrodes of each of said valves, said valves

each tending to generate oscillations of a different frequency, a source of modulating potentials connected with the control electrodes of certain of said valves for controlling the frequency of operation thereof in accordance with the modulating potentials, and a common output circuit connected with the output electrodes of all of said valves.

9. In a frequency modulation system, a plurality of valves each having a control electrode and output electrodes including an anode-cathode, a source of current connected in a cathode-direct-current circuit including the cathodes of all of said valves, means in said direct-current circuit for maintaining the sum of the anode-cathode currents drawn by all of said valves substantially constant, oscillation generating circuits comprising a transmission line terminated by a matching impedance having spaced points thereon connected between the electrodes of each of said valves, whereby said valves each tend to generate oscillations of a different frequency, a source of modulating potentials connected with the control electrodes of certain of said valves for controlling the frequency of operation thereof in accordance with the modulating potentials, and a common output circuit connected with the output electrodes of all of said valves.

10. In an electrical system a plurality of electron discharge devices each having an anode and a cathode, direct-current paths connecting the anode and cathodes of each of said devices in a direct-current circuit, an impedance in a portion of said direct-current circuit common to all of said paths for maintaining the sum of the anode-cathode direct current drawn by all of said devices substantially constant, means for controlling the conductivity of said devices in a predetermined sequence by varying the impedance between the anode and cathode thereof in accordance with controlling potentials whereby certain of said devices periodically draw more current than other of said devices and vice versa, and means for deriving output currents from the anodes and cathodes of said devices.

11. In an electrical system a plurality of electron discharge devices each having electrodes including an anode and a cathode, a time delay network comprising series and shunt reactances, a connection between the cathode of each device and a point on said network, connections between other corresponding electrodes of each of said devices and other and different points on said line, means for controlling the conductivity of said devices in a predetermined sequence by varying the impedance between the anode and cathode thereof in accordance with controlling potentials whereby certain of said devices periodically draw more current than other of said devices and vice versa, and means for deriving output currents from the anodes and cathodes of said devices.

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