April 1, 1941. E. H. B. BARTELINK 2,236,985

OSCILLATOR

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Fig. 1.

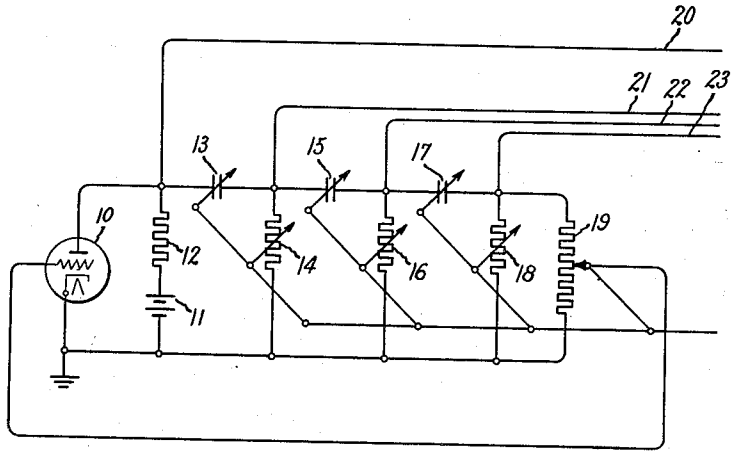


Fig. 2.

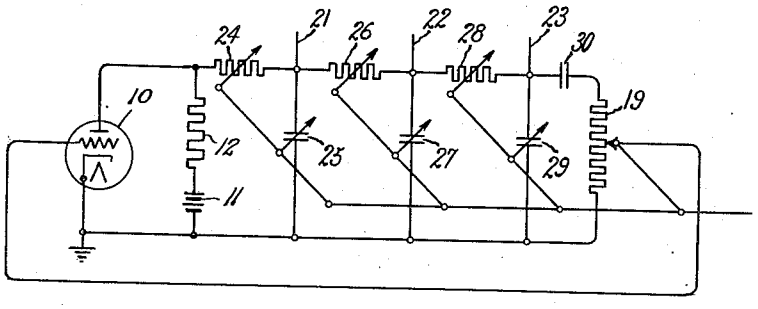
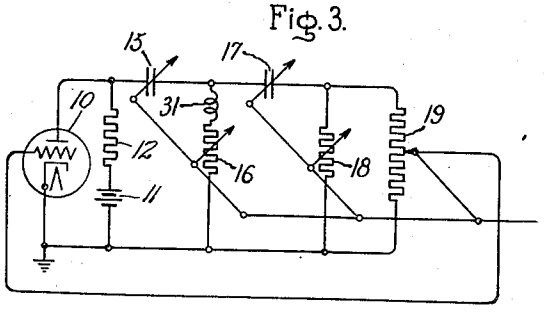


Fig. 3.



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OSCILLATOR

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3 Claims. (Cl. 250—36)

This invention relates to electron discharge apparatus and has for its object to provide improved electron discharge apparatus which is capable of transmitting a wave whose frequency is continuously variable over an exceedingly wide range.

It is of great advantage in many applications to vary the operating frequency of electron discharge apparatus over an exceedingly wide range by means of a single control. It is possible by good design of an oscillator or amplifier, tuned by inductance and capacity, to vary the frequency of the wave produced thereby over a range of about five to one. If both the inductance and capacity of a resonant circuit are varied simultaneously, the operating frequency of the circuit may be varied over a range of about twenty or twenty-five to one.

It is an important feature of my invention to employ an electron discharge amplifier device having a non-resonant feedback circuit from the anode to the control electrode thereof. The feedback circuit comprises a plurality of phase shifting networks each of which may include capacity and resistance, or inductance and resistance. By decreasing the magnitude simultaneously of every element of the phase shifting networks, the operating frequency of such an oscillator may be increased continuously about 400 times or more.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing in which Fig. 1 illustrates an electron discharge apparatus which embodies my invention, Fig. 2 illustrates a different embodiment of my invention, and Fig. 3 illustrates a still different embodiment of my invention.

Referring to Fig. 1, there is illustrated an oscillation generator including an electron discharge device 10 and a non-resonant feed-back circuit having only capacitances and resistances. This feed-back circuit is composed of three phase shifting networks, which produce voltage on the control electrode of the device 10 which is substantially opposite in phase to the voltage on the anode of the device 10.

Operating potential for the device 10 is supplied from a source 11 of direct current. The cathode of the device 10 is grounded and is connected to the negative terminal of the source 11. The positive terminal of the source 11 is connected through a load resistor 12 to the anode of the discharge device 10.

The first of the phase shifting networks in the feed-back circuit is connected between the anode and cathode of the device 10, and comprises a variable reactance 13, which is shown as a condenser, and a variable resistor 14 connected in series. Voltage variations between the anode and cathode appear across the serially connected condenser 13 and resistor 14, so that the voltage across the resistance 14 is changed in time phase from the alternating voltage between the anode and cathode of the tube 10.

In order to give the time phase of the voltage across the resistor 14 a further change, a second phase shifting network comprising a variable reactance 15, which is also shown as a condenser, and a variable resistor 16 are connected in series across the resistor 14. The voltage across the resistor 16, due to the phase shifting action of the condenser 15 and the resistor 16 is changed further in phase in the same direction from the voltage across the resistor 14 by a considerable angle.

Since it is difficult to arrange two phase shifting networks composed of resistance and reactance to produce a voltage which is shifted 180 degrees, a third phase shifting network is connected across the resistor 16. This third network comprises a variable reactance 17, shown as a condenser, and a variable resistor 18 connected in series relation. At any particular frequency of the alternating voltage between the anode and the cathode of the device 10, the voltage across the resistor 18, by suitable adjustment of the resistors and reactances in the phase shifting networks, may be made to appear exactly 180 degrees out of phase with the anode voltage.

When a suitable portion of the voltage across the resistor 18 is applied to the control electrode of the device 10, and when the discharge device has a sufficiently high amplification factor, sustained oscillations are produced. A voltage dividing resistor 19 is connected across the resistor 18 and its variable tap is connected to the control electrode of the device 10 to impress thereupon a variable portion of the voltage across the resistor 18.

To increase the frequency of oscillation of this generator it is necessary to increase the lowest frequency at which a 180 degree phase shift occurs through the phase shifting networks.

This may be effected either by decreasing the amount of reactance or the amount of resistance in the phase shifting networks. In the oscillation generator illustrated in the figure, the reactances 13, 15 and 17; the resistors 14, 16, and 18; and the voltage dividing resistor 19 are indicated as being mechanically connected together for unitary operation by a single control member. This mechanical control member is so connected to the various components that all reactances and the resistances 14, 16, and 18 are decreased or increased simultaneously. By this unitary control member the frequency of the generated wave may be varied over an extremely wide range.

Since the overall losses in the complete circuit are different in amount for each different setting, a connection to the unitary control member is provided for adjusting the amount of voltage fed from the anode to the control electrode. The mechanical control, which is connected to the adjustable tap of the voltage divider resistor 19, changes the proportional amount of voltage applied from the resistor 18 to the control electrode of the device 10 at each setting of the phase shifting networks. By suitable adjustment of the mechanical connection of the unitary control member to the adjustable tap of the resistor 19, the output of the oscillation generator is made uniform at all frequencies.

A wire 20 is connected to the anode of the device 10, from which a load device may be energized, the return circuit being through ground. If a three phase voltage is desired, it may be obtained from the phase shifting networks by suitable connections. A three phase voltage may be derived from three wires 21, 22, and 23, which are connected respectively between reactances 13 and 15, between reactances 15 and 17, and between reactance 17 and resistor 19.

Referring to Fig. 2, there is shown the feedback circuit of an oscillation generator whose phase shifting networks differ in connection from those in Fig. 1. In this case each phase shifting network in the feedback circuit is connected in shunt to the reactance of the preceding network, rather than in shunt to the resistor. The first phase shifting network comprises an adjustable resistor 24 and an adjustable condenser 25 connected serially between the anode and cathode of the device 10. An adjustable resistor 26 and an adjustable condenser 27 are serially connected in shunt to the condenser 25. The third phase shifting network includes an adjustable resistor 28 and an adjustable condenser 29 serially connected in shunt to the condenser 27. The voltage dividing resistor 19 is arranged to be connected to the cathode and to the grid of device 10 in the same way as in Fig. 1. A blocking condenser 30 is connected between the ungrounded terminal of the voltage dividing resistor 19 and the junction between the resistor 28 and the condenser 29, to prevent the anode operating voltage for the device 10 from disturbing the average grid potential, while impressing voltage variations from condenser 29 across resistor 19.

The resistors 19, 24, 26, and 28, and the condensers 25, 27 and 29 are mechanically connected together for unitary operation by a single control member in the same way as are the corresponding elements in the circuit of Fig. 1. The operation of this circuit is similar to that of Fig. 1 with the difference that the direction of phase shift is opposite. The circuit of Fig. 2 has certain advantages in some instances, since the stray circuit capacities, such as inter-electrode capacity within the device 10, appear in shunt to the variable condensers and may be made to act as a part thereof.

While the circuits shown in Figs. 1 and 2 each include three phase shifting networks, it is possible to use more or less than three such networks. If more than three are used, as in the circuits of Figs. 1 and 2, each network is adjusted to produce a correspondingly smaller change in time phase of the wave passing from the anode to the control electrode of the device 10, the total change through the networks remaining a half period of the alternating wave. Fig. 3 illustrates an embodiment of my invention using only two phase shifting networks.

If only two phase shifting networks are employed, one or both of the networks must produce a greater change in time phase than the phase shifting networks described above. In this figure a variable condenser 15, an inductance 31 and a variable resistor 16 are serially connected between the anode and cathode of the device 10. These three elements form a phase shifting network which is followed by a second phase shifting network comprising a variable condenser 17 and a variable resistor 18 serially connected in shunt to the resistor 16 and inductance 31. A voltage dividing resistor 19, which has an adjustable tap, is connected in shunt to the resistor 18. The adjustable tap is connected to the control electrode of the device 10.

Due to the existence of inductance 31 in the resistive arm of the first phase shifting network, the voltage across the resistive arm, which includes inductance 31 and resistor 16, differs by some angle greater than 90 degrees from the anode voltage of the device 10. The second phase shifting network is adjusted to change the time phase of this voltage across inductance 31 and resistor 16 by an amount somewhat less than 90 degrees so that the voltage across the resistor 19 is substantially in opposite phase to the anode voltage of the device 10.

The inductance 31 may conveniently be introduced into a resistive arm by combining it with the resistor 16. For example, the resistor 16 may be formed of wire wound on a helical form so that it exhibits inductive effects. If it be preferred, an inductance may be introduced in series with the resistor 18. Inductance may be employed in the resistive arms of both networks, if it be desired. It is to be understood that phase shifting networks of this type, which have inductance introduced into a resistive arm, are not resonant circuits. The inductance is introduced into the network only for the purpose of changing the time phase through the network in an amount somewhat greater than 90 degrees.

The apparatus illustrated in Fig. 1 may be used as an amplifier, which, although formed by non-resonant circuits, may be made resonant to a particular frequency. By adjustment of the adjustable tap on the voltage dividing resistor 10, the amount of voltage fed back to the control electrode of the device 10 may be reduced sufficiently to prevent oscillations from occurring. Under such a condition of adjustment, if a small voltage be applied between the wire 23 and the cathode of the device 10, and if it be of the same frequency to which the amplifier responds, a

corresponding larger voltage appears between the wire **20** and the cathode of the device **10**. It is, of course, obvious that the modifications illustrated in part by Figs. 2 and 3 may be employed in the same way as resonant amplifiers.

An oscillation generator or amplifier embodying my invention is capable of producing a wave whose frequency is variable continuously over approximately a 400 to 1 range. The advantage of such apparatus in certain applications is obvious. For example, for test purposes, such as for adjusting radio receivers, an oscillation generator capable of continuous adjustment by a single control in both radio and intermediate frequency ranges is of very great convenience.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto, since different modifications may be made both in the circuit arrangement and instrumentalities employed, and I aim by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. The combination in an electron discharge apparatus comprising an electron discharge amplifier device having an anode, a cathode, and a control electrode, of a plurality of phase shifting circuits connected in cascade between said anode and said control electrode, each of said circuits having input and output terminals and comprising a variable reactance element and a variable resistance element connected serially between said input terminals and means connecting said output terminals respectively to the ends of a corresponding element in each of said circuits, means for applying between said control electrode and cathode an adjustable portion of the voltage from the output terminals of the last of said phase shifting circuits, and common means for decreasing all of said elements and varying said means simultaneously to increase the operating frequency in the order of four hundred times and to maintain the output of said apparatus substantially constant.

2. The combination of an electron discharge apparatus comprising an electron discharge amplifier device having a cathode, an anode, and a control electrode, of a plurality of phase shifting circuits connected in cascade between said anode and said control electrode, each of said circuits comprising a capacitive arm and a resistive arm and at least one of said resistive arms being inductive, and common means for varying all of said arms simultaneously to vary the operating frequency of said apparatus.

3. In combination, an electron discharge device having a cathode, an anode, and a control electrode, a path for alternating current between said anode and cathode serially including a capacitive portion and a resistive portion, a second path for alternating current in shunt to said resistive portion serially including a second capacitive portion and a second resistive portion, inductance in one of said resistive portions, and means for applying a portion of the voltage across said second resistive portion between said cathode and said control electrode, whereby the phase of a wave of a certain frequency traveling through said paths from said anode to said control electrode is substantially reversed.

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