Oct. 15, 1940. E. W. HEROLD 2,217,748

NEGATIVE TRANSCONDUCTANCE TUBE-OSCILLATOR

Filed Nov. 26, 1937

Fig. 1

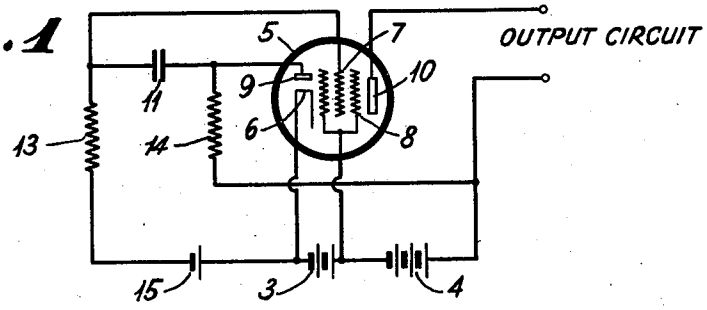


Fig. 2

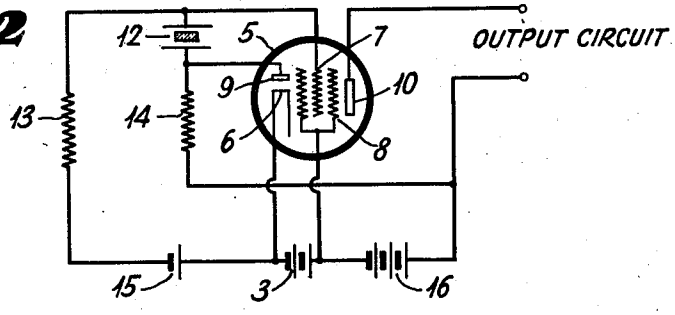


Fig. 3

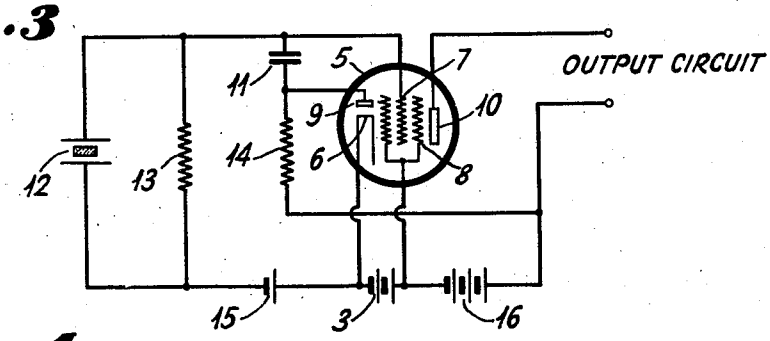
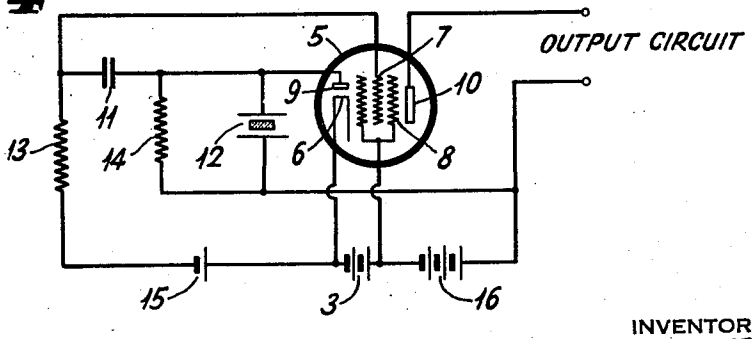


Fig. 4



INVENTOR
EDWARD W. HEROLD
BY H. S. Snover
ATTORNEY

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NEGATIVE TRANSCONDUCTANCE TUBE-OSCILLATOR

Edward W. Herold, Verona, N. J., assignor to Radio Corporation of America, a corporation of Delaware

Application November 26, 1937, Serial No. 176,548

8 Claims. (Cl. 250—36)

This invention relates to electron tube circuit arrangements suitable for use particularly as oscillators or as amplifiers. It is a feature of the circuits herein shown that they provide for the operation of an electron tube under conditions in which the tube characteristic exhibits a negative transconductance. By transconductance is meant the ratio of the change in the current in the circuit of an electrode to the change in the voltage of another electrode under the condition that all other voltages remain unchanged. A negative transconductance, therefore, would be exhibited where the output current falls while increasing the voltage on the control electrode, or where the control voltage is made less negative with respect to the potential of the cathode.

It is an object of my invention to provide suitable elements in combination and to assign suitable values to the various component parts of an electron tube circuit so that a negative transconductance characteristic may be exhibited.

It is a further object of my invention to provide a circuit arrangement where a retarding field type of negative transconductance tube having an auxiliary anode may be employed, the function of this auxiliary anode being to collect the electrons which are permitted to pass through the control grid.

As is commonly known, tubes of the type above mentioned may be used for the production of sinusoidal or relaxation oscillations in simple circuits. If any attempt is made to utilize these oscillations by conventional methods of coupling to the oscillating circuit, it is found that variations in the loading are accompanied by variations in the oscillator frequency, and amplitude, an effect obviously undesirable.

In order to reduce this objectionable characteristics it was heretofore thought necessary to insert an intermediate stage of amplification between the oscillator and the load circuit. Accordingly, it is a further object of my invention to devise a circuit arrangement which is simpler than those heretofore used in that the requirement for an intermediate amplifier stage is eliminated. I have found that this advantageous result can be obtained by the employment of a retarding field type tube having an auxiliary anode as the output electrode, the load circuit being connected to or coupled to this auxiliary anode. Since variations in the auxiliary anode potential have little effect on the negative transconductance portion of the tube which is in the screen retarding field of such a tube, it is apparent that variations in the loading of this anode circuit are practically ineffective in producing changes in the oscillating portion of the same tube.

My invention will be explained in more detail by reference to the accompanying drawing, in which

Figure 1 shows a preferred circuit arrangement having a special type of electron discharge tube the electrodes of which are connected in a suitable manner and have suitable potentials applied thereto for obtaining the advantageous oscillating characteristics set forth in the foregoing objects of the invention;

Fig. 2 shows a modified circuit arrangement in which a piezo-electric crystal may be added;

Fig. 3 shows still another modification in which a piezo-electric crystal is also used but with the connections thereto made in a different manner than as shown in Fig. 2, and

Fig. 4 represents still another modification in which a piezo-electric crystal is preferably connected between one anode and the cathode.

Referring first to Fig. 1, this circuit shows diagrammatically a special type of electron discharge tube 5, this tube being one which exhibits a negative transconductance characteristic when connected in the manner shown and described. In the instant application I am making no claim to the features of novelty of the tube itself, since that novelty which it possesses is being claimed in my Patent No. 2,139,366 granted December 6, 1938. A tube having negative transconductance appears to have been used in the past in what is known as a "VanderPol relaxation oscillator circuit." (See Philosophical Magazine, volume 2, pages 978, 992, 1926.) A feature of the tube shown in this application is that it includes a cathode 6, two grids 7 and 8 respectively, and two anodes 9 and 10 respectively.

VanderPol attributed the oscillations to a relaxation process, which inherently produces highly distorted wave forms. At a later period, and unaware of the relation of the earlier work to my own, I investigated the nature of oscillations in a somewhat different circuit, using a negative transconductance tube. I discovered that oscillations essentially true to the sine-wave form could be produced when the amplitudes were held relatively small. When the prior work of VanderPol came to my attention, I found that my discovery of this important fact had not previously been observed. My own analysis set forth in detail the theory of the sinusoidal oscillations and derived the conditions for oscillation and for the control of frequency. (See my

paper published in Proceedings of I. R. E., volume 23, pages 1201–1223, October 1935.)

I will first describe certain typical circuit arrangements which illustrate the features of the invention, after which the operating characteristics will be discussed.

According to the embodiment shown in Fig. 1, the tube 5 is provided with an input circuit extending from the grid 7 through a grid leak resistor 13 and biasing battery 15 to the cathode 6. The output circuit extends from the anode 10 through any utilization device and through anode potential source 4 and screen grid potential source 3 to the cathode 6. An auxiliary imperforate anode 9 is disposed adjacent the cathode 6 and is coupled to the input circuit by means of a capacitor 11. A suitable anode potential is supplied to this anode 9 from the source 4 by means of a circuit which includes a resistor 14.

The circuit arrangement of Fig. 2 is similar to that of Fig. 1 except that in place of the coupling capacitor 11 I preferably employ a piezo electric device 12.

The circuit arrangement of Fig. 3 differs from that shown in Fig. 2 principally in respect to the disposition of the piezo electric device. In this case it is disposed in shunt with the resistor 13 and is supplementary to the capacitor 11 which is retained in accordance with the arrangement shown in Fig. 1.

In the embodiment shown in Fig. 4 I preferably dispose the piezo electric device in shunt with the resistor 14 and also retain the use of the coupling capacitor 11 between the auxiliary anode 9 and the grid 7.

When the circucit arrangement of Fig. 1 is chosen, oscillations are produced in that portion of the tube 5 which includes the cathode 6, the control grid 7 and the anode 9. The circuit arrangement is such that energy is fed back across a capacitor 11 between the control grid 7 and the anode 9. The output circuit is connected from the cathode 6 through the screen grid source 3 and auxiliary anode potential source 4 through any suitable load to the auxiliary anode 10. This circuit is shielded from the oscillator circuit by means of the screen grid 8. In fixing the values to be assigned to portions of the circuit externally of the tube 5, certain internal capacitances must be taken into consideration. For example, there is the capacitance C_g between the grid 7 and the anode 9. There is also an inter-electrode capacitance C_p between the anode 9 and the cathode 6.

In order to stabilize the frequency of such an oscillator a piezo-electric device 12 may be employed in place of the capacitor 11. This modification is shown in Fig. 2. The circuit arrangement shown in Fig. 2 includes a resistor 13 connected between the grid 7 and the biasing source 15, the positive side of the latter being connected to the cathode 6. Another resistor 14 is connected from the positive side of the source 16 to the anode 9. By a correct choice of resistive values for the elements 13 and 14 the fundamental oscillating frequency of the circuit in the absence of the crystal may be determined. Upon introducing the crystal, however, the effective shunt capacitance of the crystal holder between the control grid and the anode 9 must be taken into consideration with due regard to the crystal frequency. The introduction of the crystal will maintain oscillations at the natural frequency of the crystal, the frequency remaining essentially stable as in the more conventional quartz stabilized oscillator circuits.

The circuit arrangement shown in Fig. 2 may be employed to produce output frequencies which are multiples or submultiples of the crystal frequency. As a frequency multiplier or divider the circuit possesses the advantages of simplicity and stability.

Referring now to Fig. 3, I show a modification in which in addition to the capacitor 11 connected as shown in Fig. 1 I also employ a piezo-electric crystal 12 connected between the control grid and the biasing source 15. The piezo-electric crystal and the resistor 13 are, therefore, shunt-connected. In certain cases the inherent tube capacitance may be sufficient so that the use of the capacitor 11 externally to the tube becomes unnecessary.

Referring to the embodiment shown in Fig. 4, I show how the piezo-electric crystal 12 may be inserted in shunt with the resistor 14. The other elements of the circuit combination are substantially the same as shown in Fig. 3. This circuit arrangement has advantageous features under certain operating conditions and the choice between the employment of either of the circuits of Figs. 3 and 4 is left largely to the discretion of the user.

Other modifications of my invention will be suggested by the foregoing specification. It will be found that in particular applications the addition of tuned circuits across any of the three major portions of the circuit arrangement, while contributing to the advantageous results to be sought, are not to be considered essential. It is a conspicuous feature of the circuit arrangements shown that stability of oscillation generation is obtained without recourse to tuned circuits.

In the foregoing disclosure of my invention only one type of negative-transconductance tube has been shown and described. It should be understood, however, that the circuits shown are directly applicable to other forms of negative transconductance tube, and that any specific type of tube in that generic class may be adopted in the circuits of my invention without departing from the spirit thereof.

While various uses of my improved negative transconductance tube circuit have been suggested in the foregoing, it may be worthy of note that other uses are contemplated such as shown, for example, in my copending application, Serial No. 148,461, filed June 16, 1937. In this last mentioned application methods are described wherein the negative transconductance tube may be used as an amplifier. In the instant application, however, I am laying stress upon the use of such a tube as an oscillator, or frequency changer.

The claims to follow are to be given the broadest interpretation which the language thereof will permit.

I claim:

1. A system for obtaining energy feed-back in a negative transconductance oscillator tube, said tube having a cathode, a plurality of grids, an output anode and an auxiliary imperforate anode, means for diverting a portion of the electrons flowing toward the output anode, means for causing said electrons to be collected by said auxiliary anode, thereby producing an oscillation generating control potential, means for impressing said control potential upon the control grid of said tube, and means including a piezo electric device

for stabilizing the frequency of the control grid circuit.

2. In combination with an electron discharge tube having a cathode, a plurality of grids, an output anode and an auxiliary imperforate anode, means for mounting said anodes so that a portion of the electron stream flowing toward the output anode may be diverted and collected by the other anode, circuit means connecting said grids to said cathode, a source of operating potentials suitably applied to said electrodes, a load element connected between the cathode and the output anode, and a piezo electric device connected between the auxially anode and one other electrode of said tube, said auxiliary anode having a capacitively coupled feedback connection to one of said grids, whereby substantially sinusoidal oscillations are generated.

3. In combination with a discharge tube having at least a cathode, a control grid, an output anode and an auxiliary imperforate electrode positioned to receive an increased number of electrons when the control grid is rendered more negative, an input circuit connected between the cathode and control grid, an output circuit including a source of operating potentials and a load connected between said cathode and said output anode, a circuit from said source of operating potentials to the auxiliary electrode, and means capacitively coupling said auxiliary electrode to said control grid whereby substantially sinusoidal oscillations are generated independently of load variations.

4. The combination set forth in claim 3 and having means including a piezo-electric device connected between two of the electrodes in said tube, for fixing the frequency of the oscillations generated.

5. An oscillator circuit arrangement comprising an electron discharge tube having a cathode, a control grid, a screen grid, an output anode and an auxiliary anode, the two said anodes being imperforate, and the output anode being shielded by said screen grid from the remaining electrodes, a substantially purely resistive and non-inductive input circuit, including a grid biasing source, connected between the cathode and control grid, feed-back coupling means connected between said auxiliary anode and said control grid, a piezo-electric device in circuit between two of the electrodes in said tube, an output circuit including a source of operating potentials and a load, said output circuit being connected between the cathode and said output anode, a substantially purely resistive and none-inductive circuit from said source of operating potentials to said auxiliary anode, a connection from said source to said screen grid, and means for so fixing the values of the working potentials applied to said electrodes in relation to their capacitances that said tube is caused to exhibit a negative transconductance characteristic.

6. A circuit arrangement in accordance with claim 5 and having said piezo-electric device connected between said control electrode and said cathode.

7. A circuit arrangement in accordance with claim 5 and having said piezo-electric device connected between said control electrode and said auxiliary anode.

8. A circuit arrangement in accordance with claim 5 and having said piezo-electric device connected in circuit between said anode and said cathode auxiliary.

EDWARD W. HEROLD.