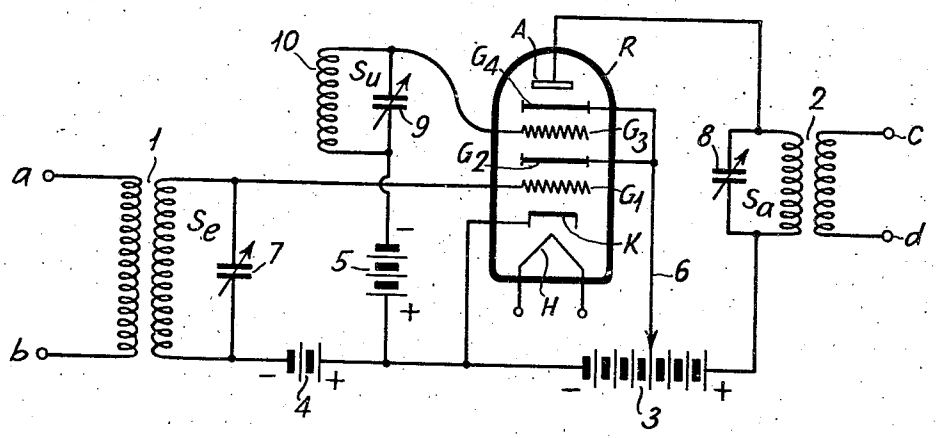
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MIXING TUBE CIRCUIT ARRANGEMENT

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MIXING TUBE CIRCUIT ARRANGEMENT

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The present invention relates to a discharge tube circuit arrangement for obtaining negative resistances. In contrast with a class of known electron discharge tubes serving for the same purpose, in the present case the electrode at which the negative resistance is to be produced is excited under the action of the electrons passing it or constituting a space charge in its vicinity. At the same time the distribution of the electrons is controlled.

In contrast with known types of negative resistance tubes, e. g. tubes using deceleration-field circuits, it is possible in this case that the electrode on which the negative resistance appears, has with respect to the real or virtual emitting point or surface of the electrons a negative bias. It is, of course, necessary that a positively biased electrode by means of which the discharge process is started, produced or maintained is placed (as seen from the cathode) behind the preferably perforated electrode connected in the circuit in which the negative resistance appears. In order to attain a reduction of damping, the operating conditions must be chosen so that with an increase of the potential of the control electrode the charge induced on the contral electrode by the electrons, in general, decreases. It follows, therefore, from this, that the dynamic capacity of the electrode on which the negative resistance appears decreases with an increase of the absolute potential of the control electrode or with a decrease of the negative bias of this electrode. The most favourable conditions of operation are obtained if the bias of the electrode in circuit in which the negative resistance appears, is chosen so that the dynamic capacity of this electrode is equal to or smaller than the static capacity of the same electrode. A little while before this state is reached the resistance of the discharge path begins to become negative and increases from this value in a negative sense until the dynamic capacity reaches its maximum negative value. The resistance of the discharge path remains negative after this point for some time, namely, so long as the charge induced in the control electrode varies in inverse proportion to the potential of this electrode.

The operation of a tube utilized according to the invention will be more clearly understood from the following discussion. The electrons which proceed in a three electrode thermionic tube from the incandescent cathode to the anode induce in the grid a positive charge, the value of which depends only on the space-charge density, at each point of the discharge space. For a plane electrode arrangement and a discharge distribution corresponding to the space-charge equation of Schottky-Langmuir, the space charge density is directly proportional to the potential at each distance from the cathode. It follows from this that under the usual idealising assumptions with regard to the grid, the total charge induced in the grid by the electrons is proportional to the effective potential, that is, it must be also proportional to the grid potential. A more circumstantial calculation shows that the total grid charge is in this case greater than the static grid charge existing in the absence of a space charge. The charge, however, influenced on the grid by the electron stream is proportional to the grid voltage only when the three halves power law is satisfied. When the characteristic curve deviates from the three halves power law, the induced charge is no longer proportional to the grid potential.

If a tube is examined with cathode, grid and anode, the characteristic curve of which is defined by the exponential function $J_a = K.U^n_{eff}$ (J_a=anode current, U_{eff}=control voltage, K=constant), one finds that the input impedance between grid and cathode changes with decreasing n from positive values through infinity to negative values. The passage through infinity lies approximately at the place where n is a little smaller than 1, i. e. the characteristic curve becomes concave towards the voltage axis (cf. the essay "The behaviour of electron tubes at high frequencies" by H. Rothe in the periodical "Die Telefunkenröhre" 1937). As the characteristic curves of tubes working with current distribution control, especially at small current densities and as long as no space charge effects are present, follow a function with the exponent $n = \frac{1}{2}$, these tubes are particularly suitable for generating a negative resistance. By measurement it can be proved that the said negative resistance appears on the control grid of space-charge-grid tubes and on the rear control grids of hexodes, octodes, etc.

If, namely, a tube is operated in such a way that near the grid a virtual cathode is formed, with a variation of the grid potential, owing to the formation and collapse of the virtual cathode an additionally induced charge appears on the grid. By differentiation the capacity increment may be obtained from this, which may reach negative values.

Now, if an alternating voltage is applied to the grid an alternating current is caused to flow in the grid circuit, which consists of two compo-

nents: the component which is due to the static capacity and the component which is induced by the fluctuating electron flow. Full consideration shows that it is only the difference between the total current and the current of the purely static case which is of importance. The alternating current induced in the grid rises, to a first approximation, linearly with the pulsatance and it also lags the voltage by an amount corresponding to the transit angle additional to the lag of a pure displacement current. The alternating current in the grid circuit obtains, therefore, a real component. The capacitative component of the alternating current, on the other hand, decreases on account of the transit angle. The measurable grid-capacity change muct, therefore, at an increasing frequency fall below the quantity determined at low frequencies. By varying the grid bias the grid-capacity change reaches the amount zero. If the grid potential is varied further in the same manner, the grid-capacity change becomes negative, that means, however, that the grid-cathode resistance must have a negative ohmic component which at the minimum value of the grid-capacity change again assumes its lowest value. For negative values of the grid-capacity change the grid current has at low frequencies, when the transit time may be considered as zero, a phase lag of exactly 90 degrees behind the grid voltage, but at higher frequencies this vector, owing to the transit angle, is rotated appreciably in a lagging direction so that a negative real current-component and, therefore, a negative ohmic conductance of the grid-cathode path appears.

According to this invention the negative resistance arising on the control grid which controls the current distribution in a multigrid tube acting as a mixing tube is used for generating the local oscillations (heterodyne oscillations).

In the drawing, a mixing tube circuit arrangement embodying the inventive idea is shown. The tube R is a hexode with an indirectly heated cathode K, four grids G_1 to G_4 and an anode A. The incoming oscillations are fed to the terminals *a*, *b* of the input circuit S_e and impressed on the negatively biased first grid G_1. The third grid G_3 is so negatively biased that the working point lies at such a section of the characteristic curve representing the connection between the voltage of the grid G_3 and the anode current, where the input impedance of this grid is negative. Then the resonating circuit S_a tuned to the local oscillation frequency is excited to generate oscillations which are multiplicatively combined in the tube with the incoming oscillations and yield the intermediate frequency which appears in the anode circuit S_a and can be taken off at the terminals *c*, *d*. The both grids G_2 and G_4 serve as screening grids and are kept on constant positive potentials. The presence of a screen grid between the grid with the negative input impedance and the anode is recommendable lest the influenced charges may be disturbed by the action of the anode alternating voltages.

The described arrangement proves itself especially in generating local oscillations of short wave length, as the negative resistance is proportional to $1/\omega^2$ (ω=operating angular velocity or natural frequency of the connected circuits respectively). But even at longer waves the arrangement grants advantages, especially as separate feed-back elements and frequency distortions often caused thereby are avoided.

I claim:

1. In a device for producing oscillations, an electronic tube having a cathode, a first grid, a control grid beyond the first grid and an electrode beyond the control grid, means providing a substantially constant flow of space current to said cathode comprising means for maintaining the potential of said first grid negative, means for maintaining said electrode at a positive potential with respect to the cathode, a tank circuit for determining the frequency of the produced oscillation, means for applying a value of negative bias to said control grid such as to make the characteristic curve relating the current to said electrode and the potential of said control grid concave toward the voltage axis of said characteristic curve at the operating point, said last named means being connected in series with said tank circuit between said control grid and the cathode.

2. In a frequency changer circuit, an electronic tube having an anode, a first control grid, a grid beyond said first control grid, a second control grid beyond said last named grid, and an anode, means for providing a substantially constant flow of space current to said cathode, means for maintaining said anode at a positive potential with respect to the cathode, means for applying energy of one frequency between the first control grid and the cathode, a source of negative bias in series with a tank circuit connected between the second control grid and the cathode, said tank circuit being resonant at a frequency which is different from the frequency of the energy applied between the first control grid and the cathode, said source of negative bias applying such a value of negative bias to the second control grid to make the characteristic curve relating the current to said anode and the potential of the second control grid concave toward the voltage axis of said characteristic curve at the operating point, and a circuit resonant to a frequency which is produced by combining said two other frequencies, connected between the anode and the cathode.

3. In a frequency changer circuit, an electronic tube provided with a cathode, a signal grid, a screening grid, an auxiliary grid and an anode, a resonant circuit connected between the auxiliary grid and the cathode, means for applying negative potentials to said signal grid and auxiliary grid, means for applying positive potentials to said screening grid and anode, said applied potentials being so related that the second derivative of anode current with respect to the auxiliary grid potential is negative whereby said resonant circuit is maintained in oscillation.

4. In a frequency changer circuit, an electronic tube provided with a cathode, a signal grid, a screening grid, an auxiliary grid and an anode, means for applying negative potentials to said signal and auxiliary grid, means for applying positive potentials to said screening grid and anode, a resonant circuit connected between the auxiliary grid and the cathode, said applied potentials being so related that the second derivative of anode current with respect to the auxiliary grid potential is negative whereby the input impedance to said auxiliary grid is negative and oscillations of the frequency of said resonant circuit are produced in said circuit.

5. In a frequency changer circuit, an electronic tube provided with a cathode, a signal grid, a screening grid, an auxiliary grid and an anode, means for applying negative potentials to said

signal and auxiliary grid, means for applying positive potentials to said screening grid and anode, a resonant circuit connected between the signal grid and the cathode, said resonant circuit being tuned to the frequency of desired signal oscillations, a resonant circuit tuned to an intermediate frequency, connected between the anode and the cathode, a resonant circuit connected between the auxiliary grid and the cathode said last named resonant circuit being tuned to a frequency which when combined with the frequency to which the first resonant circuit is tuned produces said intermediate frequency, said applied potentials being so related that the second derivative of anode current with respect to the auxiliary grid potential is negative whereby the input impedance to said auxiliary grid is negative and oscillations of the frequency of the resonant circuit connected between the auxiliary grid and the cathode are produced in said circuit.

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