May 31, 1932. E. W. B. GILL 1,861,232

FOUR-ELECTRODE VALVE AND THE OPERATION THEREOF

Filed Feb. 1, 1926

Fig. 1

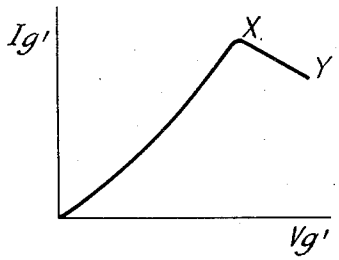


Fig. 2

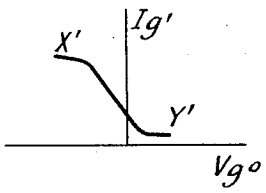
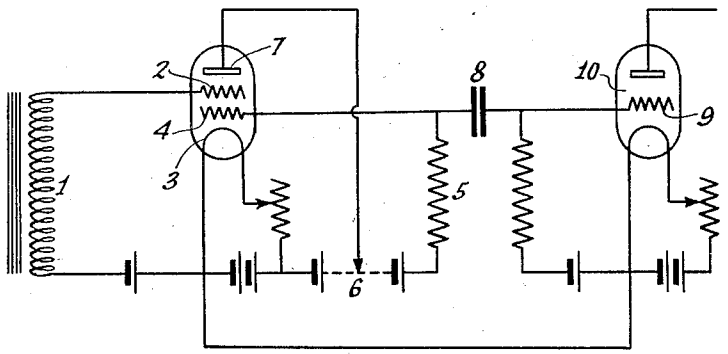


Fig. 3



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FOUR ELECTRODE VALVE AND THE OPERATION THEREOF

Application filed February 1, 1926, Serial No. 85,355, and in Great Britain February 18, 1925.

This invention relates to four electrode valves, and to means for obtaining high frequency or low frequency magnification or rectification therewith.

According to this invention the outer grid of a four electrode valve is spaced from the inner grid a distance such that when using cylindrical grids, the ratio of the diameter of the outer grid to the diameter of the inner grid is not less than 2.5 : 1, and is not greater than 5 : 1. Or, alternatively, the diameter of the outer grid is not less than 2½ times the diameter of the inner grid, and does not exceed its length.

When using flat grids, the distance from the outer grid to the inner grid must exceed the distance from the inner grid to the filament and be less than its length.

We have discovered that under suitable conditions the magnification capable of being obtained with valves so constructed will increase, possibly within certain limits, the higher the resistance inserted in the inner grid circuit.

When a high resistance is connected in the circuit of the inner grid and a suitable negative potential applied to the outer grid, the valve is capable of giving very large high frequency or low frequency magnification. The valve can also be used for rectification.

As an example, when using the valve for magnification if a resistance of 20,000 ohms be connected in the inner grid circuit of the valve and a positive potential of 40 volts applied thereto, the plate being maintained at a positive potential 22 volts, the current flowing to the inner grid circuit is .8 milliamperes approximately, when there is zero potential on the outer grid.

If, now, a negative potential of .5 volts is applied to the outer grid, the inner grid current increases by .4 milliamperes and therefore there is a change of 8 volts in the inner grid circuit, representing a magnification by 16 of the .5 volts change applied to the outer grid. If the resistance in the inner grid circuit be increased to 50,000 ohms and the potential thereof be increased to 70 volts, then when the outer grid potential is altered from zero to −.5 volts, the current through the inner grid circuit increases by .4 milliamperes, and therefore there is a voltage change in the inner grid circuit of 20 volts, representing a magnification by 40 of the .5 volts, applied to the outer grid.

When varying the resistance in, and the voltage of, the inner grid circuit, the filament emissions are also slightly varied.

The value of the outer grid voltage at which this magnification occurs can be varied by varying the filament currents.

The invention is illustrated in the accompanying drawings of which Figures 1 and 2 show typical characteristic curves obtainable from four electrode valve arrangements according to this invention, and Figure 3 shows a suitable circuit for obtaining magnification.

If in a four electrode valve, such that for any given conditions of potential the sum of the maximum currents which the outer grid and anode can pass is less than the maximum cathode emission for those conditions of potential, the outer grid be kept at a small positive or small negative potential with respect to the cathode, the anode at a greater positive potential, and the inner grid potential be varied between zero and a value greater than the anode potential, a curve of the general form shown in Figure 1 will be obtained for the relationship of inner grid potential V to inner grid current I_{g1}.

It will be observed from this curve that after a critical value of inner grid voltage has reached, a further increase of inner grid potential causes a decrease in inner grid current, i. e. there is a negative resistance effect, and that the form of the curve over the negative resistance portion X—Y is substantially a straight line.

If, now, values of inner grid current I_{g1} be plotted against values of outer grid potential V_{g0}, the anode potential being maintained at a fixed value, a curve of the form shown in Figure 2 will be obtained, the portion between X′ and Y′ (i. e. the working portion) being substantially a straight line.

Assuming that the portion X—Y of the curve of Figure 1 be a straight line, and the portion X′—Y′ of Figure 2 is also a straight line, both of which assumptions are sufficiently accurate for most practical purposes, it can be shown that $I_{g1}=C-a.\ V_{g0}-bV_{g1}$, where a, b, and c are constants. If the inner grid be charged through a resistance R by an E. M. F. Vc, then $V_{g1}=Vc-RI_{g1}$.

Hence $I_{g1}=c-aV_{g0}-b\ (Vc-RI_{g1})$, that is $I_{g1}(1-bR)=c-a.\ V_{g0}-bVc$.

If an infinitely small change dV_{g0} in V_{g0} causes an infinitely small change dI_{g1} in I_{g1}, then:—

$$\frac{dI_{g1}}{dV_{g0}}=-\frac{a}{1-bR} \text{ or } \frac{RdI_{g1}}{dV_{g0}}=-\frac{a}{b}\cdot\frac{R}{\frac{1}{b}-R}$$

$$\frac{RdI_{g1}}{dV_{g0}}=\frac{\text{change of voltage drop down R}}{\text{change of outer grid potential}}=\text{overall magnification.}$$

It will be seen that as R approaches the value $\frac{1}{b}$, the overall magnification becomes very large. We have found that in some cases $\frac{1}{b}$ can vary from 40,000 to 100,000 ohms, according to filament heating. It is thus possible to obtain a very high magnification without using an inconvenient size of resistance through which the inner grid is charged.

A suitable circuit for an amplifier comprising a four electrode valve and a three electrode valve in cascade is shown in Figure 3. The oscillations to be magnified (indicated in the drawings by the secondary 1 of a low frequency transformer) are applied between the outer grid 2 and cathode 3 of a four electrode valve, whose inner grid 4 is charged through the resistance 5 by means of the battery 6. The anode 7 is maintained at a positive potential, lower than that of the inner grid, and the magnified oscillations are coupled through the condenser 8 to the grid 9 of a triode 10.

It will be understood that high frequency oscillations may be similarly magnified by replacing the transformer winding I by the source of high frequency oscillations and that, by connecting the usual condenser and grid leak in the lead to the outer grid, rectification may be effected.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. In radio apparatus the combination of a four electrode valve having an outer grid, inner grid, anode and cathode, means for maintaining the anode potential at a positive value with respect to the cathode, means for applying to the outer grid a potential negative with respect to the cathode, and means for applying a positive potential to the inner grid, the whole arrangement being such that increase in inner grid potential beyond a critical value causes a decrease in inner grid current.

2. In a vacuum tube relay a four electrode tube having a cathode, an anode, and an outer and inner grid, an input circuit connected between said outer grid and said cathode, an output circuit connected between the inner grid and said cathode, a high resistance and source of current for charging said last named grid, a capacity in said output circuit, a second vacuum tube, and an input circuit for said last named tube connected to said capacity, whereby the potential variations in the output circuit of said first named tube are impressed on the input circuit of said last named tube.

3. In radio apparatus the combination of a four electrode valve having an anode, a cathode, an inner grid, and an outer grid the diameter of which is at least two and one-half times the diameter of the inner grid, means for maintaining the anode potential at a positive value with respect to the cathode, means for applying to the outer grid a potential negative with respect to the cathode and means for applying a positive potential to the inner grid of the valve greater than that applied to the anode, whereby an increase in inner grid potential beyond a critical value produces a decrease in inner grid current.

4. In radio apparatus, the combination of a four electrode valve, having an anode, and an inner and outer grid surrounding a cathode, an input circuit connected between said outer grid and said cathode, a thermionic triode having input and output circuits, and a resistance connected between the inner grid and cathode of said four electrode valve and to the input circuit of said thermionic triode.

5. A vacuum tube relay, comprising a four electrode tube having a cathode, an anode, and two grids, an input circuit connected between the cathode and one of the grids, a source of direct current potential connected directly to said anode, a high resistance and a source of direct current of relatively high potential connected between the other grid and the cathode, and an output circuit including a capacity having one end connected to the last mentioned grid and to the resistance, the other end of said capacity being connected to the cathode.

6. In an amplifying system, the combination of a four element tube having a cathode,

an anode and two grid electrodes between said cathode and said anode, an input circuit connected between one of said grids and the cathode, a direct current source and a high resistance connected between the cathode and the other of said grids, an output circuit including a capacity and a resistance connected between said last named grid and said cathode, and a second vacuum tube having output and input circuits the input circuit of which includes a portion of the output circuit of the four element tube.

7. In an amplifying system the combination of a four element tube having a cathode, an anode and two grid electrodes between said cathode and anode, an input circuit connected between one of said grids and the cathode, a source of potential for directly charging said anode, a high resistance and a source of potential higher than said first named source for charging the other of said grids, and a triode tube having an output circuit and an input circuit which is connected to the last named grid of said four element tube whereby the output of said second named tube is controlled by the potential variations of said resistance charged grid acting on the input circuit of said triode tube.

8. In an amplifying system, an electron device having a cathode, an anode and an inner and an outer grid interposed between said cathode and said anode, an input circuit connected between the cathode and the outer grid, a current source directly connected to said anode, an output circuit including a condenser and a resistance connected between said inner grid and said cathode, and a source of potential connecting said cathode to said inner grid through a high resistance whereby a small variation of power in the input circuit will cause a large variation of power in the output circuit.

9. In an amplifying system, a four element tube having a cathode and anode and two grids interposed between said cathode and said anode, an input circuit connecting the cathode to one of said grids, a source of power directly connected to the anode and cathode, an output circuit connecting the other of said grids to the cathode, a high resistance and a source of potential for charging said last named grid, and a three element tube having an input circuit which is associated with the output circuit of said four element tube for cascade amplification.

10. In an amplifying system, a four element tube having a cathode, an inner grid, and an outer grid the diameter of which is substantially 2½ times the diameter of the inner grid, an input circuit associated with said outer grid and said cathode, a source of potential applied directly to said anode, an output circuit associated with said inner grid and said cathode, and a high resistance for charging said inner grid, whereby the coefficient of amplification of the tube is substantially independent of the potential of the inner grid.

11. In an amplifying system a four element tube having a cathode, an anode, an inner grid and an outer grid, an input circuit connected between said cathode and said outer grid, a source of potential connected directly to said anode, and means including a source of potential and a high resistance for applying a potential to said inner grid of a value higher than that applied to said anode, whereby a high degree of amplification is obtained.

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