July 27, 1937. H. E. HOLLMANN 2,088,061

AMPLIFYING CIRCUIT ARRANGEMENT

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Fig. 1

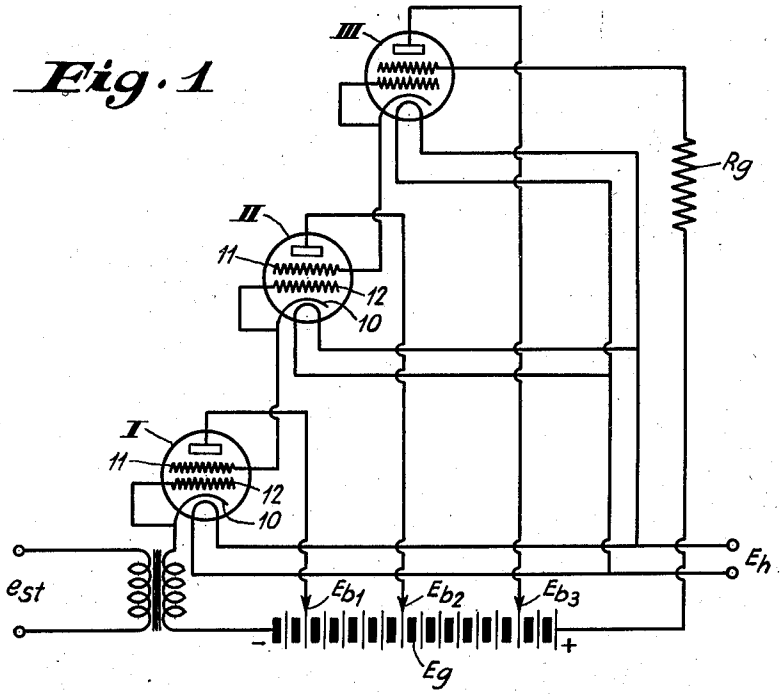
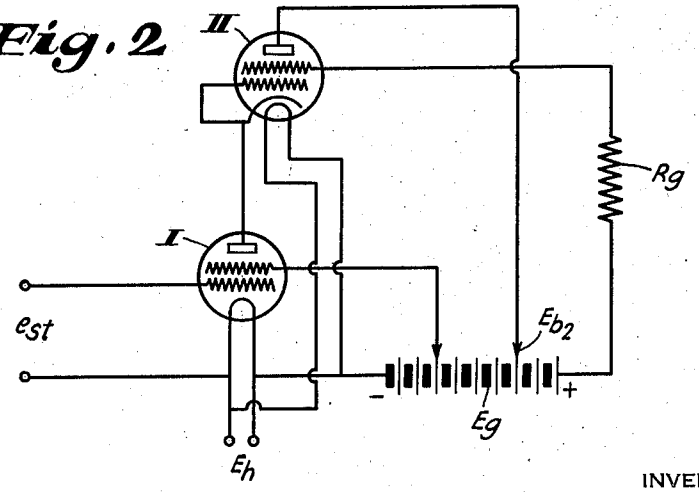


Fig. 2



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AMPLIFYING CIRCUIT ARRANGEMENT

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4 Claims. (Cl. 179—171)

The so-called retarding-field tube, that is to say, a tube operating with a positive grid (or a so-called grid anode) and a negative or slightly positive anode or plate in which the control of the current flowing to the grid is insured by virtue of the current distribution inside the tube, offers this advantage over the control of the electron current normally produced by a control grid designed to influence the space-charge, that the output potentials set up across a load resistance in the grid circuit exercise practically no effect on the distribution of the current between grid and plate, provided care be taken that it operates always inside the saturation range of the discharge current. The result is that the retarding-field tube allows of obtaining extremely high amplification factors or gains even with the simplest kind of electrode arrangement. To be sure, a certain limitation is imposed upon the general utility of the retarding-field tube as an amplifier in so far as the control action upon the distribution of the current is not accomplishable without consumption or dissipation of energy when the control potential acts on the anode, or, more correctly speaking, on the retarding electrode. For such control potential, as is known, must also control the grid current which passes through the high internal resistance of the tube. Hence, the source of the control potential itself should have only a low internal resistance in order to be able to supply this load. For this reason the scheme of cascading a plurality of retarding-field tubes has been unsuccessful, for the reason that the output resistance of each amplifier stage is reduced in an inadmissible degree by the input resistance of the following retarding-field tube stage.

In order to avoid this drawback, the control potential should not be disposed in the circuit of the retarding electrode alone, but it should, rather, be connected in that portion of the grid and anode circuits which is common thereto. This may be effected by connecting one end of the input circuit to the cathode, as later described. The source of control voltage will then be traversed only by the constant saturation current, and it works upon the infinitely high saturation resistance of the tube without any control energy being dissipated. This method proves particularly simple in the case of indirectly heated tubes, whereas directly heated tubes require a heating circuit separated from the grid supply voltage circuit. The imperfect saturation properties of indirectly heated cathodes, may be improved by the aid of a space-charge or "suction" grid. Inasmuch as the control action is then accomplishable without energy dissipation, there is no longer any practical objection to the scheme of cascading a plurality of stages containing retarding-field tubes by way of transformers, resistance-capacity couplings or other known couplings.

However, the particular properties of the retarding-field type tube become especially apparent, whenever the cascade connection according to the present invention is so chosen that each tube acts like a load resistance for the preceding tube. Since the load resistance may thus be equal to the saturation resistance, the gain per stage of retarding-field tube becomes very high.

For a better understanding of the invention reference is made to the accompanying drawing, in which:

Fig. 1 is a schematic circuit diagram of an amplifier arrangement using retarding field tubes according to the invention and,

Fig. 2 is a schematic circuit diagram of an amplifier in which a screen grid tube is coupled to a discharge tube of the retarding field type.

Fig. 1 schematically shows by way of example a three-stage retarding-field type amplifier. The cathodes 10, or, more accurately speaking, the emission electrodes of the two tubes II and III are united with the grids 11 of the preceding stages I and II, respectively. The input potential e_{st} is applied between the cathode and the negative pole of the voltage source E_g of the first or input tube, by means of the transformer shown, one end of its secondary being connected to the cathode and its other end to the battery E_g. The grid of tube III is loaded by the output resistance R_g. If all of the three tubes are to be heated in parallel, then only cathodes capable of indirect heating may be employed whose saturation properties may be improved by the provision of "suction" grids 12 which, for the sake of simplicity, may be connected directly with the cathode. The voltage variations impressed upon tube I are amplified across its load resistance, that is to say, in the tube II, and they, in turn, control the current distribution in tube II. There is brought about here a further amplification and a control of tube III until finally across the load resistance R_g the voltage variations amplified in all of the three stages are delivered. The taps E_{b1}, E_{b2} and E_{b3} are so chosen in relation to the internal resistance of each tube that their plates have lower positive potentials than their grids 11. If S denotes the slope or mutual conductance of the retarding field tubes which shall be supposed

to be the same for all of the three tubes, if moreover, R_s denotes the saturation resistance of each of the three tubes, and if finally $R_g=R_s$, then the gain obtainable by the n-stage cascade is:

$$V=\left(\frac{S\cdot R_g}{1+\frac{R_s}{R_s}}\right)^n=\left(\frac{S\cdot R_g}{2}\right)^n$$

The amplification per stage is roughly,

$$V=S\cdot R_g$$

In reality, however, the reaction of the grid, analogous to the customary plate reaction, must be taken into account, particularly if the emission is not completely saturated or, in other words, when the internal resistance R_s of the tubes is of finite value. In analogy with standard tubes there must be introduced the corrective term

$$\frac{1}{1+\frac{R_g}{R_s}},$$

or since $R_g=R_s$ this expression reduces to ½. The amplification of the individual stage thus becomes

$$V=\frac{S\cdot R_g}{2}$$

and the amplification of n stages equals this expression raised to the nth power, as in the formula first above given.

Inasmuch as in the cascade arrangement of several like stages, the load resistance is always equal to the internal resistance of the various tubes, the amplification per stage is not fully utilized, and this is expressed by the factor ½.

However, there is a fundamental change if the retarding-field tube as here disclosed is connected so as to be the load of a normal input tube as illustrated schematically in Fig. 2. For it will be noticed that in this arrangement the retarding-field tube II acts not merely as a distinct amplifier stage, but in addition as a current limiter for tube I in that it limits the anode current thereof to the value of its own saturation current. For the input tube there thus results the following amplification factor:

$$V_I=\frac{de_{st}}{de_a}=1/D$$

In other words, the first tube I operates with its full voltage gain to be calculated on the basis of its own amplification factor. Inasmuch as the amplification in tube II is $V_{II}=S\cdot R_g$, as above explained, the aggregate amplification V' is

$$V'=V_I\cdot V_{II}=\frac{S\cdot R_g}{D}$$

In these formulas D is the "controllance" and is equal to the reciprocal of the amplification factor. For instance, if in the first stage a screen-grid tube presenting a controllance D of 0.25% be used, and if the slope or mutual conductance S is, for instance, 0.2 x 10^{-3} ampere per volt, and the external resistance R_g is 1 megohm, the gain turns out to be 8 x 10^4.

It will be understood that this amplification may be raised ad libitum by the addition of other retarding-field tubes in accordance with the principle hereinbefore disclosed.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In an amplifying device, the combination of at least two similar electron discharge tube stages, each having a cathode, grid and plate arranged in the order named, an input circuit connected to said cathode and plate, an output circuit connected to said cathode and grid, means for maintaining said grid at a substantially higher positive potential than said plate, means for impressing voltage variations on the input circuit of the first stage and means coupling the output circuit of the first stage to the input circuit of the second stage.

2. The combination defined in the preceding claim in which the cathode of each of said tubes is provided with a separate heater element and a space charge grid is located between the cathode and first named grid.

3. In an amplifying device, the combination of at least two similar electron discharge tubes each having a cathode, grid and plate arranged in the order named, an input circuit connected to said cathode and plate, an output circuit connected to the cathode and grid of the second stage, means for maintaining said grids at a substantially higher positive potential than said plates, means for impressing voltage variations on the input circuit of the first stage and a direct current connection between the grid of the first stage and the cathode of the second stage.

4. In an amplifying device, the combination of at least two similar electron discharge tube stages each having an indirectly heated cathode, a grid and a plate arranged in the order named, a source of positive potential, a transformer having one end of its secondary winding connected to the cathode of the first stage and its other end to the negative terminal of said source, a lead connecting the grid of the first stage to the cathode of the second, a circuit connecting the grid of the second stage to the high potential end of said source and connections between said plates and intermediate points of said potential source.

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