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R. W. GILBERT

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THERMIONIC TUBE AMPLIFIER

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Fig. 1.

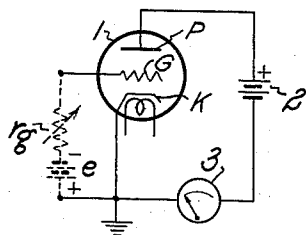


Fig. 2.

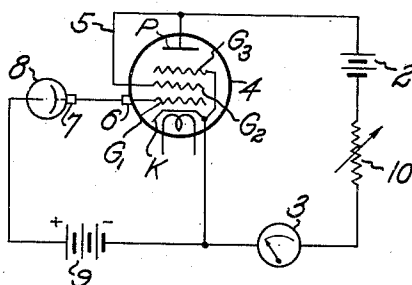
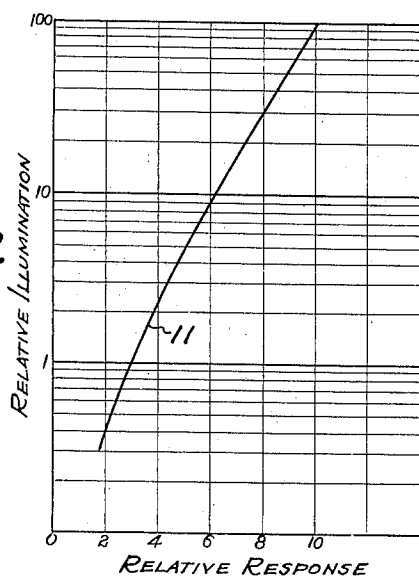


Fig. 3.



Inventor:

Roswell W. Gilbert,

By Potter, Prince & Scheffler,
Attorneys.

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THERMIONIC TUBE AMPLIFIER

Roswell W. Gilbert, East Orange, N. J., assignor to
Weston Electrical Instrument Corporation,
Newark, N. J., a corporation of New Jersey

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5 Claims. (Cl. 250—41.5)

This invention relates to thermionic tube amplifiers, and more particularly to direct current amplifiers.

Thermionic tubes have been employed for the amplification of direct currents by passing the current to be amplified through a grid-cathode resistor, thus producing a potential drop between the grid and cathode which, by the usual action of an amplifier tube, results in a change in the plate current. It has been the practice to apply a steady negative bias potential to the grid to insure negligible grid current relative to the order of the input current, and to permit adjustment of the operating point to an optimum portion of the tube characteristic. The usual plate voltages provided a substantial flow of plate current at zero input current and the usual practice has been to shunt the measuring instrument portion of the plate circuit by an adjustable voltage source to buck out this normal or "zero input" current flow through the measuring instrument. Zero stability and the amplification factor in such systems are dependent upon the settings of the grid reference voltage and the plate compensation current, and these adjustments are often critical and variable.

Objects of the invention are to provide simpler and more stable methods of and circuits for employing thermionic tubes as direct current amplifiers. Objects are to provide direct current amplifiers in which the space path resistance of the control grid against the cathode forms the load resistance for the current to be amplified. A further object is to provide a thermionic direct current amplifier in which the output or plate current falls to zero upon the cessation of a direct current input to the amplifier. Other objects relate to the provision of novel amplifier circuits in which a direct current source such as a photo-electric device is connected directly across the electrodes of a thermionic amplifier tube.

These and other objects and advantages of the invention will be apparent from the following specification when taken with the accompanying drawing in which:

Fig. 1 is a schematic circuit diagram for explanatory purposes;

Fig. 2 is a circuit diagram of an embodiment of the invention; and

Fig. 3 is a curve sheet showing the relative response characteristic of the direct current amplifier.

In the schematic diagram of Fig. 1, the reference numeral 1 identifies a vacuum tube hav-

ing a hot cathode K, control grid G and plate P. The plate circuit includes a source of current 2 and a sensitive direct current measuring instrument 3, but the grid and cathode are not connected externally of the tube. The space current path between grid G and cathode K is represented by an equivalent but fictitious circuit, as is indicated by the dotted line illustration, comprising a variable conductance k_g in series with a voltage source e .

Electrons will flow from the hot cathode to the grid and the grid potential will thus become more negative than the cathode potential. This electron flow is blocked when the grid becomes more negative than the cathode by a critical potential difference which is the "contact potential of the grid with the hot cathode." The grid-cathode conductance k_g is therefore zero when the grid potential reaches its contact potential value of $-e$ volts. The plate-cathode conductance k_p can be reduced to zero for any given negative potential on the control grid, and the amplifier action of this invention contemplates the adjustment of the plate potential to a value equal to or less than that at which plate circuit conductance is blocked when the grid is more negative than the cathode by the grid-cathode contact potential e .

Examination of the Fig. 1 circuit will show that the grid potential will be reduced if a current flow is set up, in the proper sense, through the conductance k_g . This condition of current flow can be established by connecting a current source between the grid and cathode. Any reduction in the grid potential to a value less negative than that required to block electron flow, results in a further flow of electrons to the grid and the ensuing cathode current raises the conductance k_g of the grid-cathode space path to a finite value, to carry the input current i , and the circuit balances when the plate-cathode current I_p reaches the value:

$$I_p = i \frac{g_m}{k_g}$$

where

$$\frac{g_m}{k_g}$$

is the exponential current amplification factor and g_m is the grid-plate transconductance (mutual conductance).

The appearance of even an infinitesimal positive grid current results in current flow in the plate circuit. This characteristic arises from the fact that the positive grid current causes the grid to function as a primary anode, and the dissipa-

tion of the space charge within the grid lattice occasions conduction to the secondary anode or plate. The grid may be at a negative potential with respect to the cathode because its contact potential is greater than the effect of grid current, but it functions as a true anode since it carries a positive current.

A tube circuit such as shown in Fig. 1 is particularly adapted to the amplification of small currents from sources, such as phototubes, which have zero conductance at zero current flow. It is to be noted that the grid potential varies with the input current that flows through the grid-cathode space path, and that the amplifier functions as a true amplifier of this direct current flow.

A practical application of the invention to the amplification of the direct current output of a phototube is shown in the circuit diagram of Fig. 2. The vacuum tube 4 is shown as a pentode in which the suppressor grid G_3 is internally connected to the cathode K. The screen grid G_2 is connected to the plate P by a lead 5, and the tube thus functions as a triode. The control grid G_1 has a cap terminal 6 that is connected to the cap electrode 7 of the cathode of phototube 8, the phototube anode being connected to the tube cathode K through the current source 9. The plate circuit includes the current source 2 and measuring instrument 3, as previously described, and may also include an adjustable resistance 10 for introducing plate circuit regulation to control the shape of the response characteristic.

Typical values for satisfactory operation are indicated by the following data relative to one amplifier circuit that was constructed and successfully operated. The tube 4 was a type 38 pentode and the phototube 8 was a type 919. The contact potential of the control grid G_1 with the cathode K was about -3 volts, and the plate current source 2 was adjusted to about 6 volts. The phototube current source 9 was 25 volts, and the instrument 3 was a microammeter having a full scale deflection corresponding to 200 microamperes.

The curve 11 of Fig. 3 was plotted from measurements made with the apparatus just described. The exponential form of the response characteristic makes possible the accurate measurement of small input currents as the output current is still of substantial magnitude when the input current is equal to or less than 1% of the value which produces a full scale deflection of the microammeter. Curve 11 shows that the output current for 1% relative illumination was about 50 microamperes, or 25% of the maximum output current.

It is to be noted that the amplifier tube does not function in the customary manner of an alternating current amplifier tube. The minimum plate and screen grid voltage which the tube manufacturers recommend for the type 38 tube is 100 volts, with the control grid biased to -9 volts with respect to the cathode. Plate conduction is not blocked under such conditions but, in accordance with this invention, the voltage on the plate and screen grid is at or below that value which corresponds to zero plate conduction when the grid is biased negatively by the grid-cathode contact potential only. Regulation of the plate voltage below that value will control the magnitude of the response to a given input current and it is interesting to note that there will be some amplification when the plate voltage is zero.

In actual practice, input currents as low as

10⁻¹⁴ ampere will produce a readable deflection when the microammeter 3 has a range of 0-200 microamperes, and an input of 10⁻⁷ ampere will produce a full scale reading. The invention is not restricted to the amplification and/or measurement of any particular range of small direct current values and it will be apparent that currents of an order substantially higher than those noted above may be amplified when tubes having other characteristics and measuring instruments of other ranges are employed.

The invention is distinguished from prior direct current amplifier circuits and methods by the fact that the plate current falls to zero when the grid current is zero, and that a plate current appears with even an infinitesimal positive grid current. The amplifier action has been described with reference to tubes that function as triodes but it will be apparent that the amplifier tube may operate as a tetrode or other multi-grid tube so long as the plate voltage is maintained below that value at which the contact potential of the control grid blocks plate circuit conduction.

I claim:

1. The method of operating a thermionic tube as a direct current amplifier, the tube having a cathode cooperating with a control grid and a plate, which method comprises maintaining a substantially infinite impedance between the grid and cathode, whereby the grid assumes its normal contact potential with the cathode, impressing between plate and cathode a voltage of not more than that value at which the normal contact potential of the grid with the cathode blocks plate conduction, and passing the current to be amplified through the grid-cathode space path in the direction of grid-to-cathode.

2. The method of operating a triode as a direct current amplifier which comprises maintaining a substantially infinite impedance between the grid and cathode, whereby the grid assumes its normal contact potential with the cathode, impressing between plate and cathode a voltage of not more than that value at which the normal contact potential of the grid with the cathode blocks plate conduction, and passing the direct current to be amplified through the grid-cathode space path in the direction of grid-to-cathode.

3. In a direct current amplifier, a thermionic tube having a cathode cooperating with a control grid and a plate, means maintaining the control grid at its normal contact potential with the cathode, a plate-cathode circuit including a current-responsive device in series with a source of potential, said potential source establishing a plate voltage of not more than that value at which the normal contact potential of the grid with the cathode blocks plate conduction, and a source of direct current to be amplified connected between the grid and cathode with the positive terminal of the direct current source towards the grid, whereby current flow from said source through the grid-cathode space path dissipates the space charge at the grid and renders the plate circuit conductive.

4. In a direct current amplifier, a thermionic tube having a cathode cooperating with a control grid and a plate, means maintaining the control grid at its normal contact potential with the cathode, means for energizing said tube with a plate-cathode potential of not more than that value at which the normal contact potential of the grid with the cathode blocks plate conduction, a current-responsive device connected between

plate and cathode, and a source of direct current to be amplified connected between the grid and cathode with the positive terminal of the direct current source towards the grid, whereby current flow from said source through the grid-cathode space path dissipates the space charge at the grid and renders the plate circuit conductive.

5. A direct current amplifier circuit comprising a vacuum tube having a control grid cooperating with a cathode and plate, means maintaining the control grid at its normal contact potential with the cathode, a phototube having a cathode and

anode, a connection from the phototube cathode to the control grid and a source of direct current connected between the phototube anode and the cathode of the vacuum tube, the positive terminal of said current source being towards the phototube anode, and a plate-cathode circuit including a current measuring instrument and a source of plate potential, said source of plate potential impressing on the plate a voltage of not more than that value at which plate conduction is blocked by the normal contact potential of the control grid with its cathode.

ROSWELL W. GILBERT.