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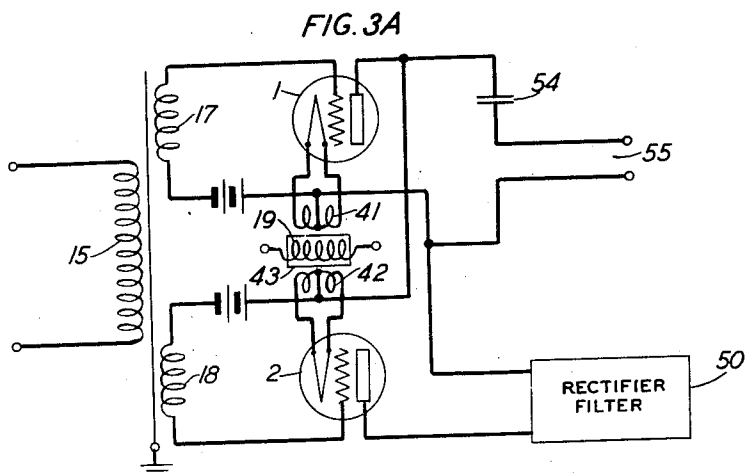
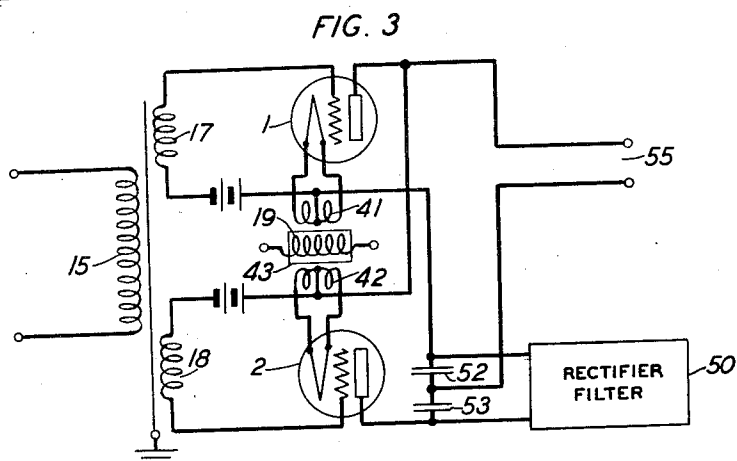
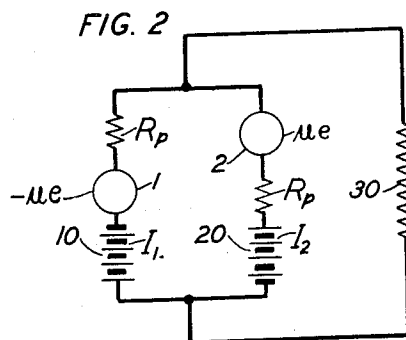
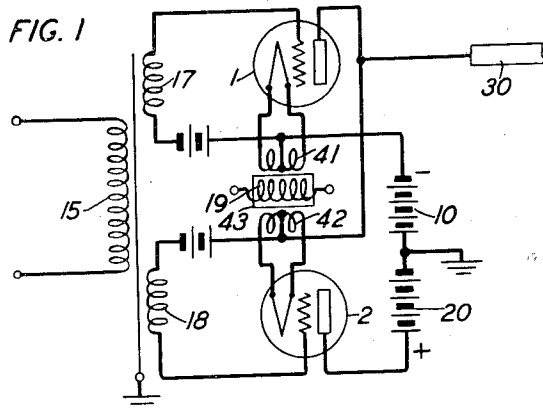
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1,944,216

SIGNALING SYSTEM

Filed May 29, 1931

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

FIG. 4.

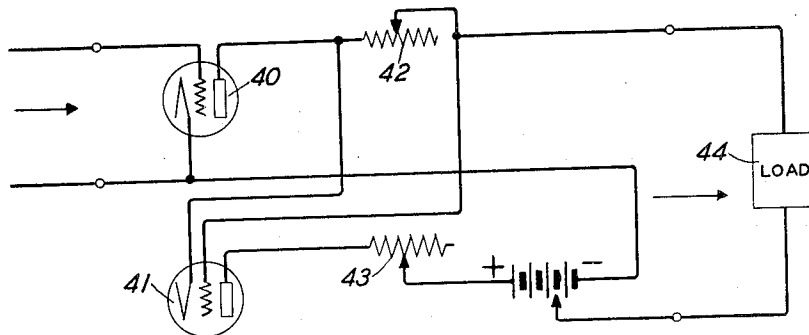
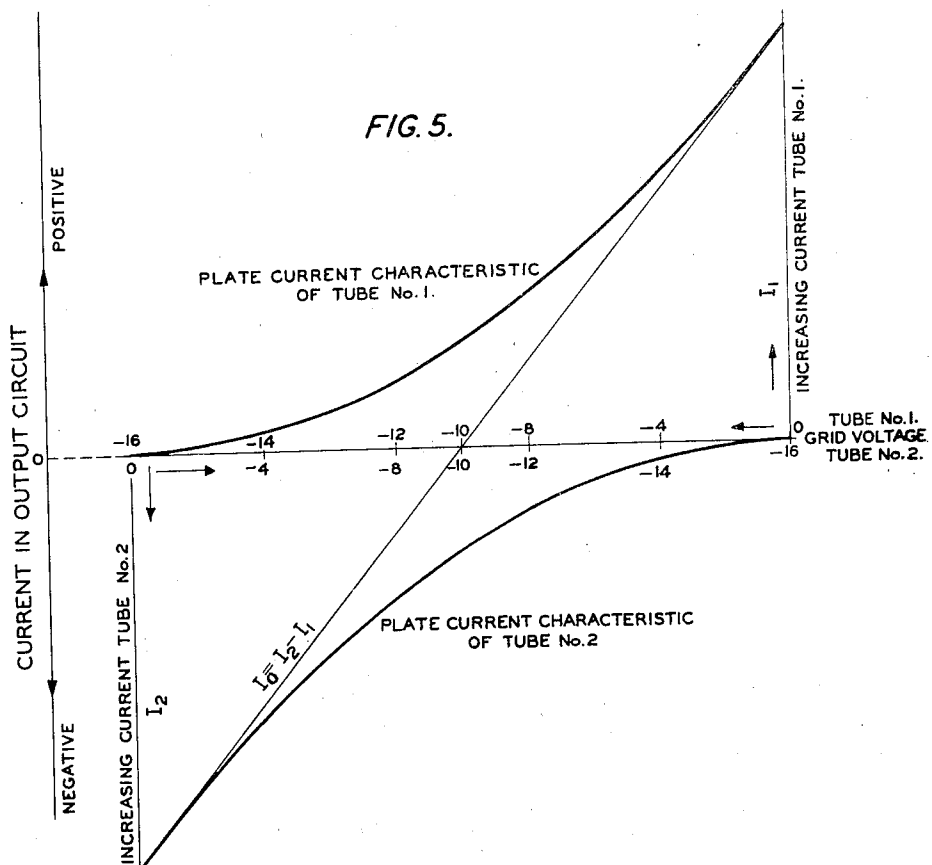


FIG. 5.



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UNITED STATES PATENT OFFICE

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SIGNALING SYSTEM

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Application May 29, 1931. Serial No. 540,825

5 Claims. (Cl. 179—171)

The present invention relates to circuits for the communication of intelligence and more particularly to repeaters for the retransmission of currents as employed in telegraphy, telephony, picture transmission, etc.

An object of the invention is to amplify impulses with decreased distortion.

Another object of the invention is to increase the output efficiency of an amplifier.

Another object of the invention is to provide a thermionic transmitter which may be used as a repeater or amplifier and in which the output current is balanced with respect to polarity.

The invention is embodied in one form in a push-pull arrangement of vacuum tubes, wherein the plate circuits of two tubes are arranged in series with each other and with a plate battery, but in parallel with the load. The voltage of the battery is twice the plate voltage of each tube. In such an arrangement each tube acts as a plate circuit resistance for the other. The varying nature of the plate circuit resistance has a tendency to compensate for the plate characteristic curvature, thereby resulting in a straight line characteristic. The output circuit or load device is connected to two points of normally equal potential in the plate circuit, which are chosen so that there will normally be no current in the output circuit. Circuit arrangements in accordance with the invention have special applicability for use with load devices to which a large current is to be supplied.

Other objects and features of the present invention will be set forth in the following description of the principles of the invention which is made in connection with the accompanying drawings, in which:

Fig. 1 shows one embodiment of the invention representing a push-pull arrangement of vacuum tubes as connected to a submarine signaling cable;

Fig. 2 shows the theoretical circuit of Fig. 1;

Figs. 3 and 3A show embodiments of the invention as applied as amplifiers in the final stage of audio-frequency amplifiers;

Fig. 4 shows a modification of the invention in which the input is supplied to one tube only; and

Fig. 5 shows curves representing graphically the combination of the output currents of tubes arranged in accordance with this invention.

In the drawings, identical reference numerals designate similar parts.

Referring more particularly to Fig. 1, two similar vacuum tubes 1 and 2 have impressed upon their grids by the balanced secondary windings

17 and 18 of transformer 15 one-half of the voltage variations of the transformer 15. The output circuits of tubes 1 and 2 and their respective anode-cathode batteries 10 and 20 form parallel branches across the output impedance which is constituted by the submarine cable 30. Since the output circuits of the two tubes are in parallel relationship, twice as much power may be supplied to the cable as would be possible with a single tube. A balanced arrangement of space discharge tubes such as described is known as a push-pull amplifier. In the usual push-pull arrangement, an inductance (for high frequencies) or resistance (for low frequencies) is connected to the two plates in the output circuit. At low frequencies, the inductance cannot be used and it becomes necessary to include a resistance in the plate circuit. A feature of the present invention is the elimination of this resistance. This the invention accomplishes by connecting the plate-filament circuits of the two tubes 1 and 2 in series with plate batteries 10 and 20 of twice the usual voltage. The voltages in the two branches are opposite in sign; therefore, when the signal input is zero, the voltages are evenly balanced against and by each other. This feature affords a convenient method of preventing the flow of current in the cable when no signals are impressed upon the input transformer. In such an arrangement, the filament current may be conveniently supplied from a power supply circuit, preferably by means of a transformer such as shown at 19 having two secondary windings 41 and 42 and a shield 43.

By substituting another space discharge device for the output circuit impedance of a space discharge device and having the output of the latter controlled in reverse phase with respect to the output of the former device, the two devices have equal effects in controlling the output, and their combined plate characteristics form essentially a straight line over the entire operating range because they are in opposite phase. Thus distortion is minimized. Fig. 5 shows such a characteristic which has been determined by applying equal and opposite direct current voltages to the two grids of space discharge tubes 1 and 2. It is seen that the output or "difference" current $I_0 = I_2 - I_1$ is a straight line for the entire operating range.

Assuming parabolic tube characteristics, the result represented graphically in Fig. 5 may be checked or arrived at by applying mathematical considerations to the theoretical circuit represented by Fig. 2. Those reference symbols of

this figure which are identical with those of Fig. 1 designate identical parts and the other symbols will be understood from the explanations given below. The fundamental equation of the thermionic amplifier has been set forth by Van der Bijl on page 156 of his book entitled "The Thermionic Vacuum Tube and its Applications", first edition, 1920, thus:

$$I_p = \alpha \left(\frac{E_p}{\mu} + E_g + \epsilon \right)^\beta,$$

where I_p is the plate current;
 α is a constant depending on the tube design;
 E_p is the plate potential;
 μ is the amplification constant;
 E_g is the grid potential; and
 ϵ is a small voltage which depends on the tube design and is usually neglected.

With an oxide coated filament the general exponent β may be assumed to have the numerical value equal to 2 and ϵ may be neglected. Making these substitutions and substituting for E_g the constant grid bias potential $-E_c$ and the input voltage ϵ one has:

$$I_p = \alpha \left(\frac{E_p}{\mu} - E_c + \epsilon \right)^2.$$

Referring to Figs. 2 and 5 and designating the output current and the output impedance with I_o and Z_o , respectively, the plate battery voltage applied to each tube E_B and the internal tube impedances of tubes 1 and 2 with R_{p1} and R_{p2} , respectively:

$$I_o = I_2 - I_1 \quad (1)$$

$$E_{p1} = 2E_B - E_{p2} \quad (2)$$

$$I_1 = \alpha / \mu^2 (E_{p1} - \mu E_c - \mu \epsilon)^2 \quad (3)$$

with respect to ground;

$$I_2 = \alpha / \mu^2 (E_{p2} - \mu E_c + \mu \epsilon)^2 \quad (4)$$

where Z_o is the load impedance:

$$I_o = \frac{E_B - E_{p2}}{Z_o} \quad (5)$$

From (1) and (5)

$$E_{p2} = E_B - Z_o(I_2 - I_1). \quad (6)$$

From (2) and (6)

$$E_{p1} = E_B + Z_o(I_2 - I_1) \quad (7)$$

From (3), (4), (6) and (7)

$$I_2 = \alpha / \mu^2 [(E_B - \mu E_c) + \mu \epsilon - Z_o(I_2 - I_1)]^2 \quad (8)$$

$$I_1 = \alpha / \mu^2 [(E_B - \mu E_c) - \mu \epsilon + Z_o(I_2 - I_1)]^2 \quad (9)$$

From (8) and (9)

$$I_o = I_2 - I_1 = 4\alpha / \mu^2 (E_B - \mu E_c) [\mu \epsilon - Z_o(I_2 - I_1)] \quad (10)$$

since

$$\frac{\mu^2}{\alpha} (E_B - \mu E_c)$$

equals the internal tube impedance R_p ;

$$I_o = 4/R_p (\mu \epsilon - Z_o I_o) \quad (11)$$

or

$$I_o = \frac{4\mu \epsilon}{R_p + 4Z_o} \quad (12)$$

It follows from (12) that the alternating output voltage e_o is:

$$e_o = I_o Z_o = \frac{4\mu \epsilon}{R_p/Z_o + 4} \quad (13)$$

All the terms of Equation (13) are linear, which

indicates the absence of harmonics or distortion.

It follows from the above analysis that the effect of two tubes in push-pull in accordance with this invention is to minimize distortion irrespective of the value of the output circuit impedance.

This freedom from effect of output circuit impedance enables the circuit of this invention to function either as a voltage amplifier or as a current amplifier. Maximum power output is obtained when the output impedance is one-half the internal impedance of either tube. In Figs. 3 and 3A are shown circuits in which the parallel push-pull principle is utilized in the final stage of an audio-frequency current amplifier. In this case the plate current may be supplied by a suitable power network. If alternating operating current is used, a rectifier and filter as shown at 50 may be inserted in the circuit leading from the alternating current power line. Condensers 52 and 53 of Fig. 3 constitute a voltage divider for supplying ground potential to the lower terminal of the load circuit 55. Condenser 54 of Fig. 3A is a blocking condenser for preventing the flow of direct current in the load circuit which may be connected to terminal 55.

In the embodiment shown in Fig. 4, the output circuit is similar to that of Fig. 1, but the input current is applied to tube 40 only. The output of tube 40 supplies input current to tube 41 by virtue of the drop of potential in the adjustable resistance 42. Resistance 42 is adjusted to a point where the grid of tube 41 receives the same voltage as the grid of tube 40. Resistance 43 is a balancing resistance equal to resistance 42. The voltage applied to tube 41 is in opposite phase relation to that of tube 40.

In this circuit, the relation between the impedance of the load 44 and the resistance of the adjustable resistance or potentiometer 42 determines the voltage delivered to the input of tube 41. It is, therefore, desirable that the load impedance remain in a definite relation to the value of the resistance 42 for all frequencies which it is desired to transmit.

What is claimed is:

1. A thermionic repeater comprising a plurality of space discharge devices having their plate circuit connected in series with a battery, a control electrode for each device connected to an input circuit, and an output circuit for the repeater, characterized in this, that the output is supplied from two points in the series circuit which are at the same potential when no current is applied to said control electrodes.

2. In a thermionic repeater, a plurality of space discharge devices, each comprising an anode, a cathode and a control electrode, said repeater having an input circuit connected to said control electrodes, the anode circuit of each device being connected in series with the anode circuit of the other device and with a source of constant electromotive force, and an output circuit connected between a point intermediate the source of electromotive force and another point in the series circuit having the same potential as the first point when no signals are applied to said input circuit.

3. A push-pull arrangement of space discharge tubes, comprising internal space current circuits and an external load circuit, the plate circuits of the tubes being connected in series with each other and with a source of plate potential, and in parallel with respect to the load circuit, whereby

one tube functions as the output impedance for the other tube.

4. A substantially distortion-free amplifier of the push-pull vacuum tube type having a balanced output, characterized in this that the plate circuits of the two tubes are connected in series with a source of plate current having twice the plate voltage of one of said tubes and that the output terminals are connected across the plate of one tube and the midpoint of said source, said plate and midpoint being of equal potential when no signals are applied to the input circuit of said amplifier.

5. A repeater comprising two electron devices, each having an anode, a cathode and a control element, an input circuit oppositely connected to said control elements, a source of operating current in a series circuit with the internal anode-cathode path of each of said devices, and an output circuit connected to points of said series circuit which are at equal potentials when no signals are applied to said input circuit.

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