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ELECTRICAL SYSTEM

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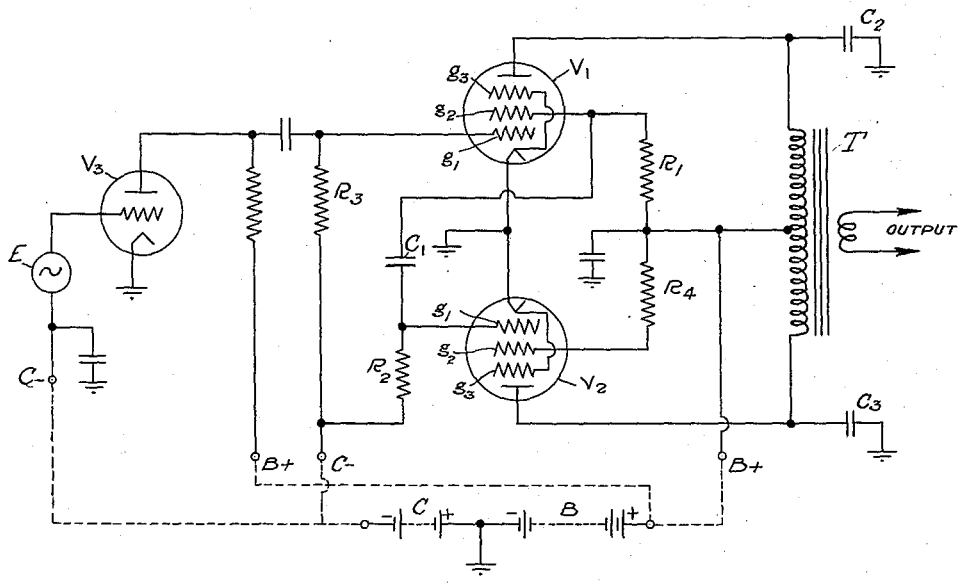

Inventor:-
Edwin L. Clark
by his Attorneys
Howson & Howson

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ELECTRICAL SYSTEM

Edwin L. Clark, Collingswood, N. J., assignor to Philco Radio & Television Corporation, Philadelphia, Pa., a corporation of Delaware

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This invention relates to push-pull vacuum tube systems and, more particularly, to a novel push-pull system for use in power amplifiers, such as those employed in the output stage of conventional radio receivers. By the present invention, there is provided a novel arrangement for obtaining the phase inversion necessary for push-pull operation of vacuum tubes.

One object of the invention is to provide a novel push-pull vacuum tube system employing a minimum number of parts or elements. More specifically, the system provided by the invention eliminates the necessity of employing either an input transformer or additional phase inversion tubes as found in conventional forms of prior systems of this general type.

Another object of the invention is to provide a novel system of this class employing space-discharge devices or vacuum tubes, at least one of which has an auxiliary anodic element such as a screen grid and wherein a signal of inverted phase is derived from the action of the said auxiliary anodic element and is applied to the input of the other tube.

A further object of the invention is to provide a system of this class wherein vacuum tubes of the "pentode" type are employed and a signal is derived from one tube and is applied to the input of the other tube through a linear network.

The invention may be more clearly understood by reference to the accompanying drawing, the single figure of which is a schematic illustration of a preferred form of the invention.

Referring to the drawing, the tubes V_1 and V_2 are of the "pentode" type having their anodes connected to the input terminals of a single center-tapped output transformer T. The cathodes of these tubes may be grounded and the anodes may be energized through a power supply unit or from a source B connected to the center tap of the primary of the output transformer. An input signal from source E may be supplied to a conventional vacuum tube amplifier V_3 and the amplified signal may be transferred through the resistance-capacitance coupling to the control grid g_1 of the tube V_1. Following conventional practice the grids of the tubes V_1 and V_2 will be designated g_1, g_2 and g_3, respectively, in order of their displacement from their associated cathode. The signal applied to tube V_1 may be obtained from any conventional source, for example, from the output of a preceding tube, as shown, or from an audio amplifier, or from a microphone or any other signal source.

The signal supplied to the control grid g_1 of tube V_1 serves to control the space current in that tube. The output signal, which is thus produced in the anode circuit, is approximately 180° out of phase, or, in other words, of opposite phase, with respect to the input signal. In accordance with the present invention, the screen grid g_2 of valve V_1 is connected to the power supply B through a resistor R_1. The element g_3 of tube V_1 may be connected to the cathode, as shown. The variations in space current of tube V_1 also causes a signal voltage to appear across the resistor R_1 and this signal is likewise approximately 180° out of phase with respect to the input signal for the range of operating frequency. Hence, it may be used to drive the other push-pull tube V_2. The signal across the resistor R_1 may be transferred to the control element g_1 of tube V_2 by means of the condenser C_1 and grid leak resistor R_2. Grid bias may be supplied to the elements g_1 of tubes V_1 and V_2 by means of grid leaks R_3 and R_2, respectively, which may be connected to a proper source of grid bias, such as the source C. It will be apparent that this bias may be obtained in any other conventional manner, for example, from a resistor and shunt condenser in the cathode circuit of tubes V_1 and V_2. As before, the element g_3 of V_2 may be connected to the cathode, and the screen grid g_2 may be connected to the B supply through a resistor R_4 or in some cases this resistor may be omitted. This will be explained in further detail hereinafter.

As has been pointed out, a signal which is 180° out of phase with respect to the input signal over the operating range is thus supplied to the tube V_2, and this tube, therefore, produces an amplified signal in the output circuit. Thus, the tubes V_1 and V_2 operate in push-pull relation to one another. The secondary or output side of the transformer T may be connected to any conventional load circuit, such as a loud speaker of the electrodynamic type or any other suitable device.

The device of the invention is well adapted for amplifier operation of the type known as "Class A" in which current flows in each tube during the entire signal cycle, or for operation of the type known as "Class AB", in which current flows for nearly the entire signal cycle. Where the circuit is designed for Class A operation, and it is desired to obtain the maximum power output without undue distortion, the magnitude of the resistor R_1 may be such that the input signal supplied to g_1 of tube V_2 is some-

what larger than the corresponding input signal supplied to g_1 of tube V_1. In a preferred form of the invention, the signal to tube V_2 may be as much as 20 to 25 per cent larger than the corresponding signal supplied to tube V_1. This is possible by virtue of the fact that the low value of the load resistor R_1 of tube V_1, which resistor supplies signal to tube V_2, permits a wide grid swing of tube V_2 without appreciable distortion. When so operated the even harmonics of the output signals of each tube will not exactly cancel and some even harmonics may appear in the output circuit. When the tubes are thus operated in unbalanced relation, the resistor R_4 may be omitted.

Where more linear amplification is desired at the expense of some sacrifice of power output, the resistor R_4 may be included and may be made equal to resistor R_1. Under these circumstances, the signal supplied to the element g_1 of tube V_2 may be of the same order of magnitude as that supplied to element g_1 of tube V_2, which makes for balanced operation and cancellation of even harmonics in the output circuit. The amplitude of the signal supplied to element g_1 of tube V_2 may be controlled by varying the value of the resistor R_1, the signal obtained thereacross being approximately proportional to the value of the resistor.

As has been mentioned above, it is desirable that the signal applied to the control grid g_1 of tube V_2 may be substantially 180° out of phase with respect to the signal applied to the control grid g_1 of tube V_1. This phase inversion or phase shift is inherent in the operation of a space discharge device, an increase in the controlling signal voltage resulting in a decrease in the output signal voltage. The necessity of this phase inversion arises from the fact that the transformer T, when used as shown in the figure, is adapted to produce in its output circuit a signal corresponding to the vector difference of the signals supplied thereto by the load circuits of the two push-pull tubes. If now, the signals applied to the control grids of the two push-pull tubes have some phase relation other than a phase difference of 180°, the output signal will be correspondingly modified. For example, if the two signals supplied to the control elements were of equal magnitude and identical phase, the output signal would be zero, and for other phase relations and amplitude relations, the signal will correspond to the vector difference, as above mentioned. Where the signal supplied to the tube V_2 is obtained from a resistance in the output circuit of the element g_2 of tube V_1, and where this signal is transferred by means of a capacitance and grid leak resistor, the desirable phase inversion of 180° will be obtained for all frequencies at which the impedance of the condenser is small as compared with the impedance of the resistor R_2. On the other hand, where the impedance of the condenser approaches that of the grid leak resistor, then a phase shift will take place between the signal appearing across the resistor R_1 and that applied to the control grid g_1 of tube V_2, and this phase change will, of course, be that introduced by the fact that this network contains appreciable reactive components. It is therefore desirable, where a uniform frequency characteristic is desired over the operating range of the device, that the cut-off frequency of the transfer network to the control element of the tube V_2 be lower than the lowest frequency which it is desired to transmit. It will further be apparent that modifications of the frequency characteristic of the amplifier may be obtained by replacing the present resistance-capacitance network by a reactive network having the property of varying the amplitude and phase relation of signals thus transferred to the control element of the second tube.

It is important to note that the circuit of the screen grid g_2 of V_1 including the resistor R_1 is independent of the output circuit for both tubes, and this independence of the two circuits is necessary to avoid regeneration. Due to the fact that the anodes of the tubes are connected to opposite ends of the primary winding of the transformer T, the output current of V_2 will tend to set up a voltage between the anode of V_1 and ground equal and opposite to that between the anode of V_2 and ground. If the circuit of the screen grid g_2 of V_1 were not independent of the output circuit including the anode of V_1, then the voltage induced on the anode of V_1 would tend to be transferred to the input circuit of V_2, and it would oscillate as a conventional oscillator. However, following the practice of applicant's invention, a circuit independent of the output circuit, except for the common source of energy (across which no signal is built up), is provided, and any tendency of the circuit to regenerate or oscillate is completely avoided. By deriving the input signal for V_2 from a circuit separate from the output circuit of both V_2 and V_1 and connected to an auxiliary element (g_2) in V_1, the current to which element is determined by the input signal for V_1, the input signal for V_2 may be made independent of the output signal and determined only by the signal supplied to V_1.

In general the tube V_1 may be any tube having an anode, cathode, a control element and an auxiliary element, such that the space current to this auxiliary element is controlled by the aforementioned control element. Thus, tubes of the type known as "tetrodes" might be used in the circuit of my invention. Preferably, however, tubes of the type known as "pentodes" should be used for the reason that by the use of such tubes the operating range and power capabilities of the system are enhanced. Where a tube of the tetrode type is used, it is desirable that the maximum voltage between the auxiliary electrode (g_2) and the cathode be less than the minimum voltage between the anode and the cathode in order to avoid the introduction of prominent third harmonics. If, on the other hand, a tube of the pentode type is used, which has a shielding element (g_3) between the auxiliary element and the plate, then this restriction no longer applies and the operating range of the device is materially increased. The presence of the additional element (g_3) further serves to minimize electron coupling between the auxiliary electrode (g_2) and anode and serves to improve the stability of the amplifier.

It will be seen that by the use of this invention, there is obtained a signal of inverted phase suitable to actuate one branch of a push-pull amplifier circuit, without the use of an input transformer or an additional phase-inverting tube other than the one tube used in the push-pull circuit. As the cost of an input transformer is substantial, the present invention effects a substantial reduction in cost as regards prior push-pull amplifiers embodying such a transformer. Moreover, by eliminating the phase-inverter tube of another prior device of this type, which tube generally provides no amplification, the device of

the invention effects an economy with respect to the said prior device. It will be seen also that the distortion inherent in such prior devices has been eliminated. As the input signal supplied to the control grid g_1 of tube V_2 is obtained from across a resistance and transferred to the control grid by means of a resistance-capacitance coupling, considerably less distortion is introduced than would be obtained by deriving such signal from across an impedance such as choke or transformer in the output circuit of tube V_1. It will further be apparent that even though the element g_2 of tube V_1 will have a signal appearing thereon, the actual variation in potential of this element will be small, due to the fact that both tubes V_1 and V_2 act as pentodes and have a high amplification factor, and for practical purposes, the tube V_1 will behave as a conventional pentode as far as its anode circuit is concerned. Thus the deriving of a signal from the screen grid of the tube V_1 will not adversely effect its performance as a power amplifier.

In the use of such a device as an audio frequency amplifier output stage, it is customary to provide by-pass elements for the purpose of limiting the high frequency response of the system. For this purpose, condensers C_2 and C_3 may be connected to the anodes of tubes V_1 and V_2, respectively, and to ground. These condensers serve in cooperation with the transformer T to provide a high frequency cut-off for the system.

In a specific embodiment of the invention, the tubes V_1 and V_2 were commercial tubes of the type known as "42" tubes and they were operated at their rated voltages. The transformer T was of such character as to transform the load impedance to appear as a resistance of about 12,000 ohms (plate-to-plate) and the resistance R_1 had an optimum value of about 4,000 ohms. In this particular case, the resistance R_4 was omitted and the resistances R_2 and R_3 were of the order of magnitude of a 200,000 ohms or more. In a modification of the invention, the magnitude of the resistance R_1 was decreased to about 2,000 ohms and the resistance R_4 was the same as R_1.

Although the invention has been illustrated and described with particular reference to a preferred embodiment employing vacuum tubes of the pentode type, it will be understood that the system may be modified or varied without departing from the invention. For example, other types of tubes may be used, as above mentioned, the invention contemplating broadly the derivation of a signal from the action of an auxiliary element of one tube in a circuit independent of the output circuit for the system, and the application of such signal to the other tube to effect push-pull operation of the tubes. It will be understood also that the invention is not limited to operation of the tubes at audio frequency. Other possible modifications will be obvious to persons skilled in the art.

I claim:

1. In an electrical system, a pair of space discharge devices, each having a cathode, an anode and a control element, and at least one of said devices having an auxiliary element, the control element of said one device being disposed between the cathode and the auxiliary element of said device, an output circuit comprising a winding and means for connecting one end of said winding to one anode and the other end of said winding to the other anode, another circuit, independent of said output circuit, for the auxiliary element of said one device, means for applying an input signal to the input of said one device, means for deriving a signal voltage from said auxiliary element circuit, and means for applying said last-named signal voltage to the input of the other of said devices.

2. In an electrical system, a pair of space discharge devices, each having a cathode, an anode and a control element, and at least one of said devices having an auxiliary element, the control element of said one device being disposed between the cathode and the auxiliary element of said device, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, the auxiliary element of said one device being connected through an impedance to said source thus forming a circuit independent of said output circuit, means for applying an input signal to the input of said one device, whereby a signal voltage is set up across said impedance, and means for applying said last-named signal voltage to the input of the other of said devices.

3. In an electrical system, a pair of space discharge devices, each having a cathode, an anode and a control element, and at least one of said devices having an auxiliary element, the control element of said one device being disposed between the cathode and the auxiliary element of said device, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, the auxiliary element of said one device being connected through a resistance to said source, thus forming a circuit independent of said output circuit, means for applying an input signal to the input of said one device, whereby there is set up across said resistance a signal voltage of opposite phase relation with respect to said input signal, and means including a resistance-capacitance coupling for applying said last-named signal voltage to the input of the other of said devices.

4. In an electrical system, a pair of space discharge devices, each having a cathode, an anode and a control element and at least one of said devices having an auxiliary element, the control element of said one device being disposed between the cathode and the auxiliary element of said device, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, the auxiliary element of said one device being connected through a resistance to said source thus forming a circuit independent of said output circuit, means for applying an input signal to the input of said one device, said resistance being of such value that there is set up thereacross a signal voltage of greater amplitude than said input signal, said signal voltage being of opposite phase relation with respect to said input signal, and means for applying said last-named signal voltage to the input of the other of said devices.

5. In an electrical system, a pair of space discharge devices, each having a cathode, an anode, a control element and an auxiliary element, the control element of each of said devices being disposed between the cathode and the auxiliary ele-

ment of said device, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, the auxiliary element of one of said devices being connected through a resistance to said source thus forming a circuit independent of said output circuit, the auxiliary element of the other of said devices being connected through a second resistance to said source, means for applying an input signal to the input of said one device, whereby there is set up across said first resistance a signal voltage of opposite phase relation with respect to said input signal, and means for applying said last-named signal voltage to the input of said other device.

6. In an electrical system, a pair of space discharge devices, each having a cathode, an anode and a control element, and at least one of said devices having an auxiliary element, the control element of said one device being disposed between the cathode and the auxiliary element of said device, an output circuit comprising a winding and means for connecting one end of said winding to one anode and the other end of said winding to the other anode, another circuit independent of said output circuit, for the auxiliary element of said one device, means for applying an input signal to the input of said one device, means for deriving a signal voltage from said auxiliary element circuit, and means for modifying the phase of said last-named signal voltage and for applying said modified signal voltage to the input of the other of said devices.

7. In an electrical system, a pair of space discharge devices, each having a cathode, an anode, a control grid, a second grid positioned between said anode and said control grid on the side of the control grid opposite the cathode, and a third grid positioned between said anode and said second grid, a conductive connection between said third grid and said cathode, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, said second grid of one of said devices being connected through a resistance to said source thus forming a circuit independent of said output circuit, means for applying an input signal to the input of said one device, whereby there is set up across said resistance a signal voltage of opposite phase relation with respect to said input signal, and means for applying said last-named signal voltage to the input of the other of said devices.

8. In an electrical system, a pair of space discharge devices, each having a cathode, an anode, a control grid, a second grid positioned between said anode and said control grid on the side of the control grid opposite the cathode, and a third grid positioned between said anode and said second grid, a conductive connection between said third grid and said cathode, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the mid-point of said winding, said second grid of one of said devices being connected through a resistance to said source thus forming a circuit independent of said output circuit, the second grid of the other of said devices being connected through a second resistance to said source, means for applying an input signal to the input of said one device, whereby there is set up across said first resistance a signal voltage of opposite phase relation with respect to said input signal, and means for applying said last-named signal voltage to the input of said other device.

9. In an electrical system, a pair of space discharge devices, each having a cathode, an anode, a control grid, a second grid positioned between said anode and said control grid on the side of the control grid opposite the cathode, and a third grid positioned between said anode and said second grid, a conductive connection between said third grid and said cathode, an output circuit comprising a winding, means for connecting one end of said winding to one anode and the other end of said winding to the other anode, and a source of anode potential connected to the midpoint of said winding, filter condensers connecting said anodes to said cathodes, said second grid of one of said devices being connected through a resistance to said source, thus forming a circuit independent of said output circuit, means for applying an input signal to the input of said one device, whereby there is set up across said resistance a signal voltage of opposite phase relation with respect to said input signal, and means for applying said last-named signal voltage to the input of the other of said devices.

EDWIN L. CLARK.